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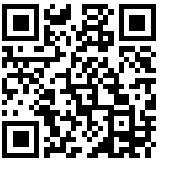

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SOME FACTORS AFFECTING RAILWAY PROJECTS IN UNDEVELOPED TERRITORIES.

A LECTURE DELIVERED AT THE S.M.E., CHATHAM, ON 13TH NOVEMBER, 1924, BY J. W. SPILLER, ESQ., M.I.C.E.

THE provision of cheap transport facilities is, perhaps, the most vital factor affecting the development of our Tropical possessions. Even in this country of short distances we realise the extent to which the cost of transportation affects the price of all commodities, but consider for a moment how much greater is the necessity for cheap transport in those undeveloped countries of vast distances within the British Empire if the interiors of those countries are to be opened to trade and their products placed on the world's markets at a reasonable price. It has been said that "Trade follows the Flag," but it would, perhaps, be more correct to say that "Trade follows the Rail," for trade can only prosper where economical forms of transport exist.

It is my privilege to talk to you to-night about some of the factors affecting railway projects which require consideration before the construction of a railway can be justified. I want you to assume that someone has suggested that a railway should be built through some particular territory and that we have been asked to report upon the proposal. We will then consider, step by step, the procedure which should be followed and the matters which must be brought under consideration to enable us to deal in an intelligent manner with all questions which may affect the cost and ultimate prosperity of the proposed railway. For the development of long-distance communications a railway naturally suggests itself as the most suitable method, but railways are costly to construct, and it is necessary in the first place to consider what alternative means of transport are available. The most primitive form of transport, one which has been employed in Tropical Africa for countless generations, is the head load. A native porter can carry on his head a load of 56 lbs. over a distance of 15 miles in a day. If he is paid a shilling a day for the forward journey and sixpence a day for the return journey light, it will be found that the cost per ton-mile amounts to four shillings. This is clearly a costly form of transport. Further, it is slow, it involves breaking bulk, it exposes the goods to risk of loss by theft or damage from the weather and it is wasteful of man power. Men employed as porters are performing duties of an unproductive character, and if a large

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percentage of the population of a territory are so employed it is obvious that cultivation must suffer. The only advantage that can be claimed for head transport is that it can be employed without any preliminary expenditure on roads or railways.

In some parts of Africa ox-drawn vehicles can be operated fairly cheaply over rough earth roads. Where such roads exist, ox transport costs about 15 pence per ton-mile by contract, but this includes no provision for the construction and maintenance of the road. Recently a very careful estimate was made in one of our African Colonies of the capital and recurrent costs of a road constructed, operated and maintained, under purely hypothetical conditions, where freight rates would be charged to cover all recurrent charges in respect of interest, renewals, maintenance and operation of freight carrying plant on the assumption that the Government would not only provide the road, but also oxen, wagons and accessories and the necessary grazing lands, outspans, water supply, camps, etc. The total capital expenditure, including oxen, wagons, etc., was estimated to amount to £1,822 per mile. The total annual expenditure was estimated to amount to about £800 per annum, and a charge of rather over a shilling per ton-mile would be necessary to cover all outgoings on the assumption that traffic would amount to at least 40 tons per day in one direction and 10 tons per day in the opposite direction.

Motor transport is another alternative to rail transport, and light lorries—like the Ford—can be operated over unmetalled roads in the dry season. If, however, a continuous service is required, metalled roads are necessary and these will cost about £2,000 per mile to construct under fairly easy conditions where suitable stone is available and about £100 per mile per annum to maintain. By petrol operated lorry the cost of transport would be about two shillings and sixpence per ton-mile exclusive of the cost of road maintenance and interest on the money expended on its construction.

The consideration of motor transport raises, naturally, the question of the relative economy of road and rail transport, but it is exceedingly difficult to reduce all the factors affecting these two forms of transport to a comparable basis. A railway is constructed, equipped and operated by a single authority who controls and makes charges for all uses to which the railway is put. A road motor service, on the other hand, may make use of roads already constructed and used for other purposes or may construct new roads. In the latter case roads so constructed would, doubtless, be available for use by the general public. While, therefore, the total cost of operating a railway, including the cost of maintenance of way and structures, is fairly chargeable against the traffic transported, it is difficult to determine what proportion of the cost of road construction and maintenance is properly debitable to a motor service using

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such roads in conjunction with other users. A railway involves heavy constructional cost and requires special equipment. The interest on capital invested is, therefore, considerable, but the operating expenses are low. A motor road, on the other hand, does not involve such costly construction and equipment charges, but the operating expenses are higher. A railway service will, then, be more economical than a motor road service if the amount of traffic to be transported is sufficient to make the saving on operating expenses justify the cost of its special construction and equipment. There is, in fact, a certain critical volume of traffic, the transport of which can be performed with equal economy by a rail service or a road service; for a greater volume a railway, and for a smaller volume a road service, would prove the more economical. It will be seen, then, that the question as to the relative economy of these two different forms of transport really involves a comparison between the critical volume of traffic and the amount which is likely to be offered, and before a decision can be reached as to which form of transport should be adopted it is necessary to estimate the volume of traffic which is likely to make use of such transportation facilities as may be provided.

In connection with the consideration of motor transport, it should never be overlooked that the tractive resistance of a steel wheel on a steel rail is about 8 to 10 lbs. per ton, while the tractive resistance of vehicles on macadam roads is about 75 lbs. per ton for roads of good surface and about 100 lbs. per ton for roads of inferior surface, a difference of 10 to 1 in favour of rail transport. This fundamental difference will always militate against cheap motor transport. In England to-day, in spite of the heavy cost of wages and materials, the total freight of the country is being handled on the railways—excluding the cost of collection and delivery—at an average cost of 1.37 pence per ton-mile. Motor transport can never hope to compete with such a figure. In Nigeria an extensive service of motors is operated by the Railway department as feeders to the railway. In 1923, 21 motors ran a total van mileage of 121,952 miles at a cost of 21 pence per ton-mile exclusive of the cost of depreciation of plant and interest and maintenance charges on the roads used. The services made use of roads having a mileage of 172 miles. If the roads cost £2,000 per mile to construct and £100 per mile to maintain yearly, and if we assume that interest charges on one-half the cost of construction and also half the cost of yearly maintenance were debitable to the motor service, the cost of operating the motor service would amount to 43½ pence per ton-mile, and this figure includes no provision for depreciation. The average receipts per ton-mile on the railway only amounted to 2.29 pence and the railway was operated at a considerable profit.

It will be seen, then, that while transport by head load involves

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no preliminary expenditure, it is slow, inconvenient, wasteful of man power and costly. Where oxen are available transport by ox wagons is cheaper than head loads, but is slow and likely to prove unreliable on earth roads in the wet season. Motors are quicker and more reliable than ox wagons, but require metalled roads which are costly to construct while a motor service is expensive to operate. Railways, while more costly to construct than metalled roads, can be operated more cheaply than motor transport if the volume of traffic is considerable. Before the building of a railway can be justified it is necessary, therefore, to make an estimate of the volume of traffic which is likely to be offered, and this involves an economic survey of the area to be served.

PRELIMINARY EXAMINATION OF AREA TO BE SERVED.

A close estimate of the cost of building a railway cannot be prepared until a detailed survey has been made, and this involves time and money. In order to determine if the cost of a detailed survey can be justified, it is necessary to make a preliminary examination of the area to be served, and as the result of such examination, to prepare approximate estimates of the cost of construction, equipment and probable working results. It may appear to incline to optimism to hope to make even an approximate estimate of the cost of building a railway until the detailed survey has been completed, but in the case of a pioneer railway the cost of materials and freight will amount to about one-half of the total cost of construction, and this portion of the expenditure can be estimated with considerable exactitude. Of the work in the field the quantity of earthworks is the most difficult item to estimate, but the cost of earthworks in moderately easy country does not usually exceed 15 per cent. of the total cost. An experienced engineer, after he has travelled through the country between the terminal points as close to the proposed route as may be possible, should be able to estimate, from his knowledge of what other lines built through similar country have cost, within a margin of 10 per cent. It is, however, more difficult to estimate the probable revenue.

Before commencing his investigations, the engineer should obtain all maps and statistics relating to the area and should collect all possible information from those who have knowledge of the country, such as, in a British Colony, the Director of Agriculture, the Director of Forests, Political Officers, etc. Such information as he may be able to obtain should not be accepted as correct, but should be verified by actual investigation. His investigations should be directed to obtaining information on the following matters :—

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(*a*) Area and chief physical features of country to be served.
(*b*) Monthly rainfall.
(*c*) Names, situation and population of chief towns, villages, markets, etc.
(*d*) Fertility of soil and area suitable for cultivation.
(*e*) Chief industries and where situated.
(*f*) Situation of mines and yearly output.
(*g*) Situation and approximate area of forests and proportion of marketable timber.
(*h*) Acreages of principal estates, proportion of area cultivated, tonnage of produce and where it will be placed on railway.
(*j*) Probable increase of production if railway is built.
(*k*) Present means of transport, cost and saving anticipated if railway is constructed.
(*l*) Amount of vehicular traffic on existing roads and number of licensed vehicles in district.
(*m*) The topography and geology of country along line of proposed railway.
(*n*) Any factors that may materially affect the cost of construction, such as necessity for tunnels, bridging, rock cuttings, etc.

The various estates should be tabulated with particulars of acreage under cultivation, commodity produced, estimated production per acre, tonnage available for export and length of haul. The production per acre of different crops will vary materially according to the fertility of the soil and the ability of the farmer. Estates supervised by Europeans will produce more per acre than native cultivations. The following figures give an indication of the probable yield of certain Tropical crops :—

Seed Cotton	300-600 lbs. per acre.
Lint Cotton	100-200 lbs. ,, ,,
Maize	1 ton ,, ,,
Tobacco	4 cwts. ,, ,,
Sugar Canes	20 tons ,, ,,
Sugar	1¾ to 2½ tons ,, ,,
Molasses	80 gallons ,, ,,
Rum	27 ,, ,, ,,
Cured Cacao Beans . . .	5 to 6 cwts. ,, ,,
Cocoanuts	2 tons ,, ,,
Copra	1000-1300 lbs. ,, ,,

The " Inwards " tonnage of each estate with respect to food supplies, fertilisers, plant, etc., should be ascertained. The output of mines, forests, etc., must also be estimated and the probable traffic therefrom determined. The receipts from passenger traffic will depend largely on the density and earning powers of the population. Experience shows that the African native takes readily

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to travelling by train, and passenger receipts may be expected to be not less than 20 to 25 per cent. of the revenue from goods traffic. There will also be further revenue from the carriage of mails, parcels and miscellaneous receipts.

The locomotives and rolling stock necessary to equip the line can be determined when the probable volume of traffic has been estimated. Where the traffic is seasonable and not equally distributed throughout the year, the number of locomotives and vehicles must be based on the most intense period plus an allowance of 20 per cent. for locomotives and 10 per cent. for carriages and wagons to provide a margin for vehicles out of commission while under repair. Additional engines will also be required for shunting purposes.

The operating expenses will depend mainly—but not entirely—on the volume of traffic and are usually based on the actual cost of operating similar railways, but modified as may be necessary if the cost of labour, coal, etc., is materially different. The estimate of operating expenses should be divided under the following main heads :—

(*a*) Maintenance and renewal of permanent way.

(*b*) Maintenance and renewal of locomotives and rolling stock.

(*c*) Locomotive running expenses.

(*d*) Traffic expenses.

(*e*) Management and general charges.

If the amount by which the gross revenue exceeds the working expenses is capitalised the justifiable expenditure, viewed from the economic standpoint only, on the proposed railway is obtained.

While a commercial company who builds a railway will expect to make a profit sufficient to pay a fair return on its outlay, a Government or State may consider it is justified in constructing a line, even though the likelihood of its paying its way is remote. It may be desirable for strategic reasons, or by opening up new country it may improve trading facilities from which the State may benefit indirectly, which may justify a loss on working. A concrete example will be quoted of a British Colony increasing its revenue indirectly, as well as directly, from railway extensions. Railway construction in the Gold Coast was commenced in 1898 and in that year cocoa exports amounted to 185 tons. By 1921, 276 miles were open for traffic, and in that year cocoa exports amounted to 133,195 tons, of which 109,114 tons were brought to the coast by railway. The export dues collected by the Colony on cocoa during the six years 1916 to 1921 amounted to nearly two million pounds or one-third of the total capital cost of the railway. Without the means of transport provided by the railway the bulk of the cocoa exports could not have been marketed at a profit.

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Again, it should be remembered that a branch line, which may itself be operated at a loss, may bring such additional traffic to the main line that the net gain to the main line may exceed the loss on the branch.

The information obtained in the preliminary examination must be embodied in a report with the estimates already referred to. It should be accompanied by a small scale map showing the approximate route of the proposed railway, the ruling points, existing roads and paths, chief towns, etc., and we will assume that the report is sufficiently encouraging to justify the comparatively small cost of making a detailed survey, but before the survey can be commenced it is necessary to determine the economic values of the major and minor details of railway location.

Major Details of Railway Location.

The two factors which affect to the greatest extent the cost of construction in the field are the ruling gradient and the radius of the sharpest permissible curve. It is clear that if there is no limit to the gradients and curves that may be employed the cost of earthworks can be reduced to a small amount. There is, of course, a limit to the grade which it is possible for an adhesion locomotive to climb even though it is hauling no load; on a steeper grade the wheels will slip. A gradient of 1 in 25 is generally regarded as about the steepest gradient which ordinary adhesion locomotives can operate successfully, but examples can be quoted of even steeper grades. On two Colonial railways of 2-ft. 6-in. gauge gradients of 1 in 23 have existed for many years, while on the Guagaquil and Quito railway of 3-ft. 6-in. gauge there is a continuous 49-mile grade averaging over 4 per cent. with many long stretches of 5½ per cent. It is, of course, only in mountainous countries that such grades can be justified, and in average country it is generally possible to obtain much easier grades without excessive earthworks.

Ruling Grade.—The ruling grade is so called because it is the gradient which limits the number of wagons per train, and it is not necessarily the steepest gradient on the profile. One of the objects which should be aimed at when laying out the line is to make the demand on the locomotive as nearly uniform as possible under normal operating conditions. If, at a certain point, the velocity of the trains has to be increased, as when starting from a station, in addition to overcoming the normal grade and rolling resistances, the gradient is in effect increased at that point. If at another point velocity can be acquired before reaching it and then surrendered, the grade is in effect reduced. There is little objection, therefore, to a short steep ascending gradient following a descending grade and such short steep gradient would not be the ruling gradient,

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although possibly the steepest gradient on the section. If a locomotive is increasing the speed of its train it is in effect overcoming the train resistance of a level track, the grade resistance of whatever gradient it may be on and that of a grade equivalent in effect to the acceleration resistance. It is then exerting the total effort for a grade equal to the actual grade plus the grade of acceleration. Such a grade is called the "virtual grade" because the locomotive is said to be doing the work corresponding to uniform speed on such a grade. A "velocity" profile for any proposed railway can be drawn when the grade profile is known by calculating the probable speeds at a sufficient number of points and plotting them as ordinates and connecting their tops. It is the velocity profile which must be studied in connection with locomotive work and in the design of gradients, for the gradient of the track may be virtually steeper or less steep than its nominal rate. The steeper the ruling gradient adopted the less the cost of construction, but the greater the cost of operation, and considerable skill is required to select that gradient which will ultimately prove the most economical having regard to interest charges on the cost of construction and the cost of operation.

On the level, train resistance at constant velocity is due to journal friction, rolling friction, air resistance, imperfections of the permanent way, etc., and varies considerably for different speeds. At starting it may amount to as much as 18 lbs. per ton, but rapidly drops to perhaps 10 lbs. per ton at a speed of one mile per hour; it drops still further—but less rapidly—to a minimum which occurs at a speed of about eight miles per hour. It then rises gradually and, at high speeds, may reach the resistance at starting. It can be assumed that, with modern rolling stock on pioneer railways, train resistance amounts to from 8 to 10 lbs. per ton at ordinary freight train speeds. On gradients there is the further resistance of gravity, and since the total resistance on gradients is made up of two factors, one of which does not vary with the gradient, the train loads on gradients do not vary directly with the slope.

A resistance of 18 lbs. at starting on the level is equivalent to a virtual gradient of 1 in 125, and since a locomotive must be competent to overcome this resistance, it would appear that there is no advantage gained in securing a flatter ruling gradient. It must, however, be remembered that freight trains usually have slack couplings and the wagons, in consequence, start one at a time. The locomotive has, therefore, attained some speed when it receives its full load and train resistance has fallen materially. It does not appear, however, to be worth while spending money to obtain ruling gradients flatter than 1 in 250, and we can assume that our ruling gradient should be somewhere between the extreme limits of 1 in 25 and 1 in 250.

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Where the volume of traffic is considerable an appreciable reduction in the ruling grade may permit a reduction in the number of trains necessary to handle that traffic with a corresponding saving in operating costs depending upon the number of train-miles saved. At the present time the cost of running freight trains on Colonial railways amounts to about twelve shillings per train-mile, but it will be realised that not all the items which make up train-mile costs are affected by a reduction in train mileage. No change in the salaries of general officers, cost of advertising, etc., can be anticipated from any small change in the number of trains. Again, a considerable portion of the cost of maintenance of way is due to weeding, trimming banks, cleaning drains and culverts, painting bridges, etc., which are quite independent of train mileage. Further, any small alteration in the number of trains is not likely to affect the number of station staff, signalmen, etc. On the other hand, the cost of trainmen's wages, fuel, maintenance and renewals of locomotives, etc., will vary almost directly with train mileage. The actual percentage of train-mile costs saved by a small reduction in train mileage will vary on different railways, but will generally be between 40 and 50 per cent. If we assume the saving is 40 per cent. and a train each way is saved per week the total annual saving will amount to $\frac{2 \times 40}{100}$ of 12 shillings $\times 52 = £25$ per mile of track. If we can borrow money at 5 per cent. we are justified in spending an average sum per mile of £500 in order to effect a reduction in the ruling gradient which will have the result of saving one train per week in each direction. This figure is somewhat on the full side since, if the number of trains is decreased by increasing their weight, the cost of running the heavier trains will be higher, but the correction necessary on this account will be small. This example serves to show the importance of correctly choosing the ruling grade. It will be seen, then, that steep grades can be justified where the traffic is light, but where a heavy traffic may be anticipated the saving on train working will justify a considerable expenditure to obtain low ruling grades.

Balance of Grades for Unequal Traffic.—If the movement of traffic is likely to be permanently heavier in one direction than in the other the ruling grade opposed to the lighter traffic may be made heavier than that in the opposite direction on the assumption that a portion of the wagons will be unloaded in one direction. For pioneer railways ruling grades of 1 in 100 against the heavier traffic—usually exports—and 1 in 80 against the lighter traffic—usually imports—are common.

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DEGREE OF MAXIMUM CURVATURE.

Just as there is a limit to the gradient which a locomotive will ascend, so also is there a certain limit of curvature which a locomotive can traverse depending principally on the length of its fixed wheel base. While gradients limit train loads it would be quite exceptional to find it necessary to introduce a curve in any alignment which would have the effect of limiting train loads. Even locomotives with eight coupled wheels can traverse curves of very short radius provided some of the driving wheels have thin or blind flanges and the gauge is slightly eased. On the hill railways in Ceylon of 5-ft. 6-in. gauge many curves of five chains radius exist, and although such curves limit speed and increase the cost of maintenance it cannot be said that they limit train loads provided the gradients are adequately compensated for curvature. It can be assumed that under ordinary topographical conditions the necessity will rarely, if ever, arise of introducing curves which are likely to limit train loads or prevent the use of engines of normal design.

MINOR DETAILS OF RAILWAY LOCATION.

The minor details of railway location are :—

Distance.
Rise and fall.
Curvature.

Distance.—It is obvious that the shorter the line the less will be the cost of operation, other things being equal, and additional expenditure on construction is justifiable in order to secure a shorter route. Distance affects fuel costs, maintenance of way costs, wear and tear on rolling stock, etc., and, if the distance saved is considerable, may affect train wages. Wellington, in his book on "The Economic Theory of Railway Location," estimated that for small changes in length about 40 per cent. of the total cost per train-mile was affected—assuming a saving in train wages—and about 25 per cent. if train wages were not affected. For greater changes in length he estimated the corresponding percentages would be about 50 per cent. and 36 per cent. respectively. In Nigeria, before the war, location engineers assumed that a saving in length of line would result in a saving per annum per daily train in each direction of £80 per mile for distances affecting wages of train men. Train-mile costs were then about six shillings; they are now twelve shillings, so the above figure should at the present time be increased by 100 per cent.

Rise and Fall.—Gradients affect train running costs in two distinct ways; in the first place the ruling grade, by limiting the number of wagons per train, increases the cost of operating the entire line, while in the second place there is the direct cost for wear and tear and fuel of ascending to and descending from any given elevation,

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instead of running on the level; in other words, the cost of rise and fall. While the latter objection to gradients is less important than the former, it requires consideration.

Rise and fall is the rise in feet on an ascending grade and the corresponding fall on some descending gradient. Between any two stations the amount of rise and fall is obtained by adding half the sum of the rises to half the sum of the falls. This is not strictly correct for a journey in one direction only, if the stations are at different elevations, but most calculations in which this quantity is used are based on trains running the round trip, and in these circumstances the rule is satisfactory. Rise and fall can be divided into three classes :—

A. Not requiring the shutting off of steam nor use of brakes.
B. Requiring the shutting off of steam at the head of the grade, but not the use of brakes.
C. Requiring the use of brakes in the descent.

Class A does not affect operating costs to any material extent, but since the speed of descent must be greater than the speed of ascent, the wear and tear on rolling stock and permanent way will be increased slightly.

Class B.—The steam used to run an engine any distance will be about the same whether the work is uniform for the whole run or is all done during the first portion in taking the engine up an easy grade from which it descends by gravity over the second portion, but while steam is shut off there will be wastage of fuel by radiation and slow combustion. Further, additional fuel will be used on the ascent since economy of fuel consumption decreases as work of engine increases.

Class C.—The use of brakes in class C materially adds to the wear and tear of rolling stock.

In Nigeria before the war it was estimated that the elimination of one foot of rise and fall would result in the following savings per annum per daily train in each direction :—

Class B.— 5s. on minor grades.
9s. 6d. on ruling grades.
„ *C*.—10s. 6d. on minor grades.
14s. on ruling grades.

These figures are for a line of 3-ft. 6-in. gauge.

Curvature.—Train resistance is increased by curvature, which also adds materially to the wear and tear on rolling stock, and permanent way. Wellington estimated that in America the addition to operating costs per degree of curvature amounted to .0593 of the cost per train mile. In Nigeria, before the war, it was estimated that the elimination of one degree of curvature would result in an annual saving per daily train in each direction of two shillings on

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an uncompensated road and 1s. 8d. on a compensated road. It is usual to compensate for curve resistance by reducing the grade on all grades where the combination of curve resistance and grade resistance would more than equal the grade resistance of the ruling grade. A usual allowance is 0.03 ft. per 100 ft. per degree of central angle; this is equivalent to assuming that curve resistance is equal to 0.67 lbs. per ton per degree.

It will be seen that just as there is a certain cost of operating each train-mile of distance, so there is a certain cost of operating each train-foot of rise and fall and each train-degree of curvature. The amounts will vary in different countries, but the locating engineer must estimate their value in order to be able to compare alternative routes when engaged on the survey.

SURVEY AND LOCATION.

The type of country which presents the greatest obstacles to railway location is that covered with dense jungle. Let us assume that our hypothetical railway has to be taken through such country. How should the survey be conducted in order to ensure a satisfactory location?

It should be remembered that railway location is really "the collection of data to permit the designing of an economical plant to handle a certain volume of traffic." Further, between the two terminal points there may be any number of alternative routes which may comply with the prescribed conditions regarding ruling grade and maximum curvature, but varying as to cost, distance, rise and fall and curvature. One of those many routes is the best, and it is the object of the survey to find that best route. Experience in jungle countries shows that the following separate surveys are necessary:—

(*a*) Reconnaissance of route.
(*b*) Preliminary survey.
(*c*) Trial survey.
(*d*) Permanent survey.

Following the preliminary survey, a preliminary location is made on which the trial survey is based, while the final location is based upon the permanent survey.

Reconnaissance of Route.—The reconnaissance is really an exploration of the country between the controlling points, and usually the exploration of more than one route is necessary. It involves the examination of as wide an area as possible along all promising routes and the elimination of as many of these routes as possible. The natural drainage lines of the country generally point the way to the best line. Precision is not required and distance can be determined by pacing, direction by a pocket compass, and heights

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by an aneroid. Notes should be made of all mountain ranges, hills, rivers, geological formation, vegetation, hardwoods, softwoods, towns and villages, mines and plantations, the fertility or otherwise of the country, the density of the jungle, points for collection of traffic, etc. The information obtained on the reconnaissance should be embodied on a small scale map and report.

Preliminary Survey.—The preliminary survey is run over routes considered acceptable under the reconnaissance survey and serves to eliminate the unsuitable and to determine the possibility of constructing a line over a selected route. More precision is necessary than is possible on the reconnaissance, but a detailed topographical survey is not required.

A width of 150-ft. or so on each side of the centre line should be surveyed along the most rational location and notes recorded of all suitable alternative lines which should be further examined on the trial survey. It should be made with a prismatic compass and chain and levels should be taken every 100-ft. with a dumpy level. On ground sloping transversely clinometer cross sections should be taken to assist in plotting a contoured plan on which to project the location. The preliminary survey should define an "area of economic location" without attempting to obtain the best available location in detail. It should be plotted to a scale of 20 chains to one inch and a working plan of four chains to the inch should also be made. A longitudinal section should also be plotted from the levels taken, to a horizontal scale of four chains and a vertical scale of 20-ft. to one inch.

Preliminary Location.—When plotted the preliminary survey enables alternative locations to be compared, first with regard to probable traffic, second with regard to ruling grade, and last with regard to the minor details of distance, rise and fall and curvature. The projection should commence at terminal and other ruling points and be sketched in tentatively at first. Two or three alternative projections should be tried and carefully studied, and their examination will indicate the approximate position of the best route on which the trial survey should be based.

Trial Survey.—On the trial survey all alternative lines should be examined and the topography elaborated to permit of the projection of the most economical line. Longitudinal sections should be taken along the centre lines of roads, tracks, water courses, etc., which are within five chains of the centre line. Major details will have been determined before the trial survey is commenced, but every possible route should be compared from the point of view of minor details. While the preliminary survey determines the "area of economic location" the trial survey is run with the object of selecting the best route in that area. Careful notes should be made of the

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annual and highest flood levels of all rivers and information obtained to enable an accurate estimate of the cost of construction to be made, *e.g.*, materials available for use in construction such as timber, gravel, sand, stone, etc., sites for brickfields, camps, etc., means and cost of transport, probable average cost of jungle clearing, nature of ground to determine the rate of earthwork, etc.

Permanent Survey.—On the permanent survey a strip of country lying within a distance of 300-ft. on each side of the centre line should be completely surveyed in such detail as to be suitable for plotting to a scale of four chains to one inch. Cross sections for 100-ft. on each side of the centre line should be taken at every 100-ft. and plotted to a natural scale of 20-ft. to one inch. From these cross sections accurate contour lines should be plotted on the survey. In addition, longitudinal and cross sections should be taken of all rivers crossed by the railway. Not less than three cross sections are necessary, one where the centre line crosses the river and one 100-ft. up stream and another 100-ft. down stream. A complete survey of each river requiring a waterway of over 200-lin.-ft. should be made within a distance of half-a-mile on each side of the centre line and cross sections should be taken. Borings or trial pits should be sunk to determine the nature of soil in cuttings and the probable depth and character of foundations.

Final Location.—The final projection is made on the permanent survey, from which it is set out with theodolite on the ground.

It will be seen, then, that the reconnaissance is really an exploration of the country and serves to determine that one or more routes are possible. On the preliminary survey these routes are examined in some detail, the least suitable routes are eliminated and an "area of economic location" is established. The trial survey enables the most suitable line within the "area of economic location" to be determined and provides the material for making an accurate estimate of cost, while from the permanent survey the centre line is set out and the railway is built.

It may not generally be conceded that four separate surveys are necessary to establish the route of a railway, and the outline I have given you of how the survey work should be conducted may be regarded by some people as a policy of perfection. The description I have given you is applicable to jungle country. In more open country of easy character the preliminary and the trial or the trial and the permanent survey may be combined into a single survey. It should, however, be remembered that a serious error in major details cannot afterwards be rectified except at great cost and may seriously affect the ultimate efficiency of the railway. It has occurred too often in the past that insufficient time and money have been allowed for the survey although every additional pound spent on the survey might quite conceivably have saved £5 in the

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cost of construction. More money can be saved by careful survey than can ever subsequently be saved by the most efficient carrying out of the work of construction.

With the completion of the permanent survey the final estimate of cost can be made, but before we consider the question of estimating I want to say something with regard to the choice of gauge.

Selection of Gauge.

If a railway exists to which the proposed railway may some day connect, the gauge of the new railway should be the same as the existing line, even though the prospects of connection are exceedingly remote. Cases have occurred in the past where the construction of a railway has commenced which it was thought would never be extended to such an extent as to permit connection with existing lines located many miles away, but both lines have subsequently been extended towards each other, and, in course of time, the possibility of actual connection becomes a practical proposition. It is necessary, therefore, to take a wide view and to bring under consideration the gauges of all railways with which the possibility of connecting to is not a physical impossibility.

Some of the evils of break of gauge, such as the actual cost of transshipment, the delay involved thereby and the loss due to breakage and pilfering, are obvious, but there are even greater objections which are less apparent, such as the detention to rolling stock necessitating a larger reserve of stock and the impossibility of pooling the stock of the two systems, when an unusually large amount of traffic is offered on one of the systems. If, however, a line is projected in a territory where connection to another line is considered to be impossible, it is necessary to determine with great care the gauge which is likely to prove the most appropriate. Railway gauges can be conveniently divided into three groups :—

(*a*) Narrow gauge with width between rails of 2-ft. 6-in. and under.

(*b*) Broad gauge with width between rails of 4-ft. 8½-in. and over.

(*c*) Medium gauge with gauges between the limits of the narrow and broad, but usually metre or 3-ft. 6-in.

Owing to the fact that the actual cost of constructing broad gauge railways in the past has generally materially exceeded the cost of building lines of medium gauge, the assumption is sometimes wrongly made that a broad gauge railway must, of necessity, cost materially more to construct than a railway of smaller gauge, but this is not the case. Provided the bridges and permanent way are designed for equal axle loadings, the cost of a railway is not greatly affected by variations in the width of gauge of moderate amount. It is by no means impossible to build a broad gauge line cheaply, and

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the Northern railway in Ceylon, of 5-ft. 6-in. gauge, was constructed before the war for £3,617 per mile, its only differences from the standard form of construction in the Colony being the employment of a lighter permanent way and the omission of passenger platforms at the less important stations. There are over 3,500 miles of 2-ft. 0-in. and 2-ft. 6-in. gauges in India, and their average cost of construction exceeded the above figure for a 5-ft. 6-in. gauge line.

It is sometimes argued that the cost of constructing a narrow gauge railway is materially less than a railway of broader gauge owing to the possibility of eliminating costly earthworks by the introduction of curves of short radius, but the importance of this factor can be very easily exaggerated. The length of fixed wheel base is the chief factor determining the limiting radius of curve, and as wheels of small diameter are usually employed on narrow gauge railways the fixed wheel base is less, but wheels of small diameter can be used with broad gauge engines. The customary limits of curvature are :—

Broad gauge	5	chains radius.
Medium ,, ...	3	,,
Narrow ,, ...	1¼	,,

Curves of 5 chains radius have been freely used on the 5-ft. 6-in. gauge hill railways in Ceylon and the 4-ft. 8½-in. gauge railways in Jamaica, and curves of shorter radius would not generally be recommended on railways of smaller gauge except in very difficult country.

If a comparison is made between alternative estimates for a metre gauge and a broad gauge line to carry similar axle loads, it will be found that while economy can be obtained by adopting the metre gauge with regard to earthworks, bridging and permanent way, the remaining items in the estimate are not affected to an appreciable extent. It is usual to adopt a sleeper 6-ft. 6-in. long for metre gauge track and 8-ft. 6-in. long for a 4-ft. 8½-in. gauge track. There should be a sufficient width of ballast outside the ends of the sleepers to give them lateral support and a sufficient cess outside the edge of the ballast to prevent it being lost down the slopes. It will be seen then, that it is only necessary to make the width of formations in cuttings and embankments greater on broad gauge lines than on narrow gauge lines by the difference between the lengths of the sleepers. Assuming a 14-ft. width of formation for the metre gauge line and a 16-ft. width of formation for the 4-ft. 8½-in. gauge line, the approximate number of cubic yards of embankment per mile with side slopes of 1 on 1½ for the above two widths are as follows :—

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Depth of fill or cut.	14-ft. width of formation.	16-ft. width of formation.	Increased earthwork due to greater width.
3 ft.	10,900 cub. yds.	12,100 cub. yds.	11 per cent.
6 ft.	27,100 ,,	29,500 ,,	9 ,,
9 ft.	48,600 ,,	52,100 ,,	7 ,,
12 ft.	75,400 ,,	80,100 ,,	6 ,,
15 ft.	107,500 ,,	113,400 ,,	5 ,,

It will be seen that the additional earthwork required for the wider gauge is likely to be less than 10 per cent. Savings will be effected in the cost of permanent way by the adoption of the narrower gauge of perhaps 20 per cent., due to the shorter sleeper and reduced width of ballast, while there will be a saving of perhaps 5 per cent. on bridging on account of the shorter culverts and reduced lengths of cross girders and bracings between main girders of bridges. In a particular instance where the relative cost of the two gauges was investigated in connection with a railway project in one of our Colonies, it was found that the total difference amounted to about 10 per cent. Alternative estimates for the construction of a North to South Transcontinental railway in Australia indicated that a 4-ft. 8½-in. gauge line would only cost about 10 per cent. more than a line of 3-ft. 6-in. gauge.

With regard to the cost of equipment, it is generally agreed that the cost of rolling stock for a given volume and description of traffic is approximately the same for metre gauge as for broad gauge. Similarly with working expenses, for equal average earnings per mile the working expenses are nearly the same on the two gauges, assuming permanent way and bridges of equal strength, but are slightly in favour of the broad gauge.

It will be seen, then, that with permanent way and bridges of equal strength a medium gauge railway costs about 10 per cent. less to build and can be operated nearly as cheaply as a broad gauge line. A broad gauge railway does, however, possess definite advantages over lines of narrower gauge. It has a wider load gauge and, owing to its greater width of base, can be operated at higher speeds and the ultimate capacity of a broad gauge line is probably twice as great as a medium gauge line. If, therefore, the amount of traffic which may be developed in the future is likely to exceed the capacity of the narrower gauge, the additional cost of constructing the broader gauge is justified.

It must not, however, be overlooked that the capacity of a railway of any gauge can be increased by strengthening the permanent way, bridges, etc., to take heavier engines. Assuming the maximum axle loads on a 45-lb., 60-lb. and 80-lb. rail are 9 tons, 12½ tons and 18 tons, respectively, the tractive power that can be developed

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with eight coupled wheels is 20,000 lbs., 27,000 lbs. and 47,000 lbs., respectively. It is possible, therefore, to increase the capacity of a pioneer line laid with 45-lb. rails by relaying with 80-lb. rails and strengthening the bridges to take 18-ton axle loads. This is the normal method of increasing capacity and, incidentally, reducing the cost of operation, and this method has actually been employed in several countries. The South African Railways show what is possible on a 3-ft. 6-in. gauge line, and although over 15,000 miles of metre gauge railways have been built in India, in only a very few cases has traffic developed to such an extent as to render widening of the gauge, or duplication of the line, necessary. In undeveloped territories of smaller population than India it is not likely that traffic will develop for many years to come to justify the construction of railways with a wider gauge than 3-ft. 6-in.

So far we have only considered the relative merits of broad and medium gauge railways, but it is necessary also to consider the possibilities of the narrower gauges of 2-ft. and 2-ft. 6-in. The primary objections to these small gauges is the lack of lateral stability, necessitating slow speeds, and the limited space available for the firebox and the moving parts of the locomotive. In consequence of these limitations it is impossible to design a locomotive with a tractive power comparable with metre gauge engines. The tractive effort, at 75 per cent. of the boiler pressure, of the 60 c.m. (1-ft. 11⅝-in.) gauge locomotive used during the war was only 5,415 lbs. The axle loads of these engines did not exceed 3½ tons. With a gauge of 2-ft. 6-in. it is possible to design locomotives with a tractive effort of 11,000 lbs. with axle loads of 5 tons. This very serious limitation of the possibilities of narrow gauge railways has been reflected in the very small mileage of such lines which have been constructed. In India, where there are over 18,000 miles of broad gauge and over 15,000 miles of metre gauge, there are only about 3,600 miles of narrow gauge, the bulk of which has a gauge of 2-ft. 6-in. Most of these narrow gauge railways are feeder lines.

The only advantage of the narrow gauge is cheapness in first cost. The light axle loads of the locomotives permit the use of a light standard of permanent way. A 20-lb. rail will suffice for the 3½-ton axle loads on the 2-ft. gauge and a 30-lb. rail for the 5-ton axle loads on the 2-ft. 6-in. gauge, with a corresponding reduction in the size and cost of the sleepers and all fastenings. When comparing, therefore, the cost of the narrow with the medium gauge we must not forget that we are doing so from a somewhat different standpoint to that on which a comparison has been made between the medium and broad gauge railways, where the assumption was made that the permanent way and bridges would be of similar strength for both gauges.

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About three years ago tenders were obtained from British contractors for the construction of a railway in Africa, 125 miles long, of 3-ft. 6-in. gauge and alternatively of 60 c.m. gauge. The 3-ft. 6-in. gauge line was to be laid with rails weighing 45-lb. per yard and steel sleepers weighing 70-lb. each, and the 60 c.m. line with 20-lb. rails and 18-lb. sleepers, but it was stipulated that earthworks and bridges should be the same in both cases and designed for 12-ton axle loads. The amounts quoted for the 60 c.m. gauge line were approximately 70 per cent. of those quoted for the 3-ft. 6-in. gauge line. If earthworks and bridges for the 60 c.m. gauge line had been made sufficient only for that gauge, an additional saving of perhaps 4 per cent. would have been obtained. The line proposed was in easy country and the cost of the 60 c.m. gauge line—exclusive of the cost of rolling stock, land and compensation and supervision—would have amounted to about £4,088 per mile.

While the cost of construction is materially less the saving on maintenance will not be so marked. One of the chief factors affecting maintenance costs in tropical countries, where vegetation grows at an appalling rate, is the time spent on weeding the track. Owing to the slightly reduced width of formation some saving will be effected in this respect, while the cost of materials used on maintenance should also be less. On the other hand, the lighter permanent way is more easily displaced under working conditions and by heavy rains, while the cost of patrolling the line will be the same for both gauges.

With regard to running costs there can be no question that they will be higher on the narrow gauge line unless the volume of traffic is exceedingly small. With a 3-ft. 6-in. gauge line and 9-ton axle loads it is possible to design locomotives with a four times greater tractive effort than with a 2-ft. gauge line and 3½-ton axle loads. It is therefore necessary to run four trains, with four train crews, on a 2-ft. gauge line where one train with one crew will suffice for a similar quantity of traffic on a 3-ft. 6-in. gauge line. In India the average cost of moving traffic on the 2-ft. gauge lines is more than double that on the metre gauge.

The ultimate capacity of a single line of railway depends upon the number of trains which can be passed over the railway during any definite period. This will depend mainly on the distance between crossing stations and the speed. If the permissible speed on the 3-ft. 6-in. gauge is double that on the 2-ft. gauge and the carrying capacity of each train is four times greater, then the ultimate capacity of the wider gauge is eight times that of the smaller. It will be seen, therefore, that while the cost of constructing a 2-ft. gauge is materially less and the cost of maintenance slightly less than the cost of a 3-ft. 6-in. gauge line, the working expenses are likely to be materially greater per ton-mile, and its ultimate

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capacity will only be a fractional part of the wider gauge. Owing to its limited traffic-carrying capacity a narrow gauge railway cannot be regarded as suitable for a railway of any considerable length as, though the volume of traffic in immediate sight may not be sufficient to justify the present construction of a wider gauge line, if the railway is to fulfil its primary purpose of opening for development an extensive tract of country, the growth of traffic may necessitate the conversion of the narrow gauge railway in a few years hence. When this eventuality occurs the cost of conversion will probably amount to double the present saving and the line will subsequently be burdened by interest charges on a considerable amount of dead capital. At the same time it must not be overlooked that the volume of traffic is independent of the gauge, and a revenue, which might give a satisfactory return on a small capital outlay, may prove inadequate to pay the interest charges on the larger expenditure which the construction of a broader gauge may involve. Generally it will be found that this condition exists in the case of branch or feeder lines only.

The foregoing analysis of the characteristics of a 2-ft. gauge line is applicable—but in a lesser degree—to railways of 2-ft. 6-in. gauge. The additional six inches in the width of gauge enables the tractive power of the locomotives to be increased 100 per cent., while higher speeds are possible. While, therefore, the ratio between the two gauges is as 4 is to 5, the ratio of the ultimate capacities is nearer 4 to 12.

Having regard to all the circumstances, the most suitable gauge for a pioneer railway is probably the metre or 3-ft. 6-in., and this view is confirmed by the extensive mileage of these gauges which has been constructed.

FINAL ESTIMATE OF COST.

The estimate of the cost of construction should be sub-divided under convenient main-heads, such as :—

(1) Survey.
(2) Purchase of land and compensation.
(3) Clearing.
(4) Earthworks.
(5) Bridges and culverts.
(6) Ballast.
(7) Permanent way.
(8) Stations, buildings and water supply.
(9) Telegraph.
(10) Sanitation and maintenance of labour camps and hospitals.
(11) General charges, supervision, etc.

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The main heads should be sub-divided where necessary into :—

(*a*) Cost of materials f.o.b. British Port.

(*b*) Cost of freight and transport to site.

(*c*) Cost of work at site.

The cost of materials can be estimated with little difficulty and may amount to 50 per cent. of the total cost of the work. Ocean freight will be in the neighbourhood of £2 to £3 per ton weight or bulk, to this must be added insurance at, say, eight shillings per £100. Landing charges will depend upon the facilities available and may be between 7s. 6d. and 15s. per ton. Freight up country over existing railways should not exceed 2d. to 3d. per ton-mile.

When materials have to be transported a considerable distance into the interior, the cost of freight and transport may reach a considerable sum.. In the case of one of the railways to which I have referred it was necessary, after landing on the other side, to transport the materials over four different railways as well as to ferry them across a big river. Freight and transport was estimated to amount to over £7 per ton. It will be readily seen how seriously this affected the cost of construction. A ton of cement which could, perhaps, have been purchased here for £4 was worth £11 at rail base. Similarly, rails which might be purchased here for, say, £9 per ton would be worth £16 delivered at site.

The cost of work at site should be based on recent costs of similar work when such information is available. It will depend on the quantity, quality and physique of the labour available as well as on the rate of wage paid, although, if comparisons are made between different countries, it is usually found that the cheapest labour is generally the least efficient, being deficient in either skill or physique, and more often in both.

The following unit rates are representative of present-day costs in Tropical Africa :—

Clearing	Light bush . .	4/6 to 6/- per square of 100-ft.
,,	Heavy bush . .	9/- to 15/- ,, ,, 100 ,,
,,	Light forest . .	20/- to 45/- ,, ,, 100 ,,
,,	Heavy forest . .	45/- to 100/- ,, ,, 100 ,,
Excavation	Soft earth .	9d. to 1/3 per cubic yard.
,,	Hard earth .	1/3 to 2/- ,, ,,
,,	Rock (soft) .	2/- to 3/- ,, ,,
,,	Rock (hard) .	4/6 to 7/6 ,, ,,
Concrete		60/- to 70/- ,, ,,
Steel Bridgework (erected)		£30 to £45 per ton.
Ballast (1,500 cub. yds. per mile)		3/- to 8/6 per cub. yd.
Laying, lifting and packing permanent way . . .		£140 per mile.

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Telegraph (3 wires), materials delivered at site	£140 per mile.
Erecting telegraph	£50 ,,
Major Stations	£2,500 each.
Minor Stations	£1,200 ,,

The following details of the most recent estimate I have seen for a railway extension in Africa, 79 miles long, are of interest :—

	Cost per Mile.	Percentage of total cost.
	£	
Survey	65	0.92
Land	31	0.44
Earthworks	968	13.72
Major Bridges	288	4.08
Minor Bridges	441	6.25
Fencing	11	0.16
Telegraph	238	3.37
Ballast and Permanent Way	3057	43.31
Buildings and Fixtures	517	7.32
Station Machinery	270	3.82
Furniture	47	0.67
Plant	41	0.58
General Charges	1084	15.36
Total Cost per Mile	7058	100.00

In this lecture it has been possible to treat in a general way only the matters brought under consideration, and experience shows that it is dangerous to generalise on transport problems as they are almost invariably affected by particular circumstances peculiar to each locality. While it must not be forgotten that the physical characteristics, climatic conditions, labour costs, etc., all of which affect transportation costs, vary in different countries, and even in different districts of the same country, I hope that the information I have been able to give you will some-day prove helpful when considering transport developments.

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THE ROYAL BOMBAY SAPPERS AND MINERS.

War Memorial at Kirkee.

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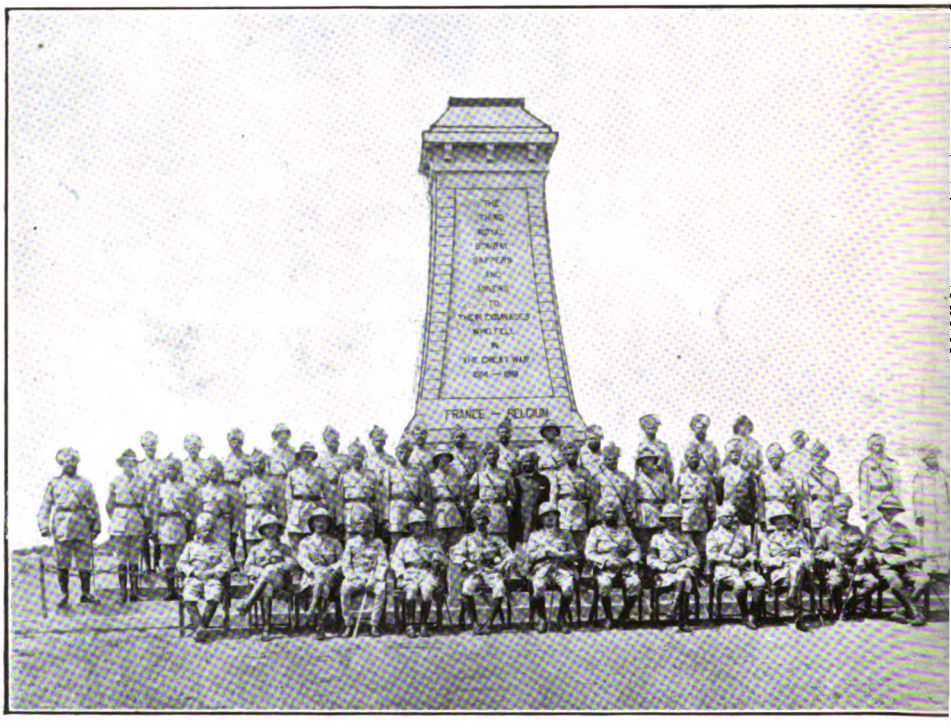
THE WAR MEMORIAL OF THE ROYAL BOMBAY SAPPERS AND MINERS.



Group taken at the Unveiling Ceremony at Kirkee.

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THE ROYAL BOMBAY SAPPERS AND MINERS.

Unveiling Ceremony of the War Memorial at Kirkee.

The War Memorial of the Royal Bombay Sappers and Miners was unveiled by H.E. The Governor of Bombay on 10th September, 1924. The Corps was drawn up in three sides of a square round the Memorial. On arrival of H.E. he was received with a Royal Salute by a Guard of Honour, consisting entirely of men who had fought in the Great War, and of whom the large majority were wearing the 1914 or 1914-15 Star. After inspecting the Guard of Honour, H.E. took up his position facing the Memorial. At the conclusion of the dedicatory prayers by the Chaplain, Moulvi, Granthi and Pandit, Colonel on the Staff G. H. Boileau, C.B., C.M.G., D.S.O., R.E., as the most senior officer present, who had served with the Royal Bombay Sappers and Miners, asked H.E., on behalf of the Corps, to unveil the Memorial. H.E. then made the following speech :—

"I consider it a great honour to be asked to unveil this Memorial to-day to the memory of the officers and men of the Royal Bombay Sappers and Miners.

"The Corps, into which is now incorporated two units of the old Railway Battalion, served with credit and distinction on many fronts during the Great War, and in every theatre of operations secured high praise for its services. Two Companies, the 20th and 21st, were mentioned in despatches by name for their gallantry at Neuve Chapelle in 1914, the 17th Company was similarly mentioned for gallant service at Shaiba, as was the 22nd Company for gallantry at Sahil and Essinn, and in all these actions the Companies lost heavily in officers and men.

"On the conclusion of the War His Majesty the King-Emperor conferred the title of 'Royal' on the Corps, an honour conferred on only eight units of the Indian Army, and one which, before the Great War, had never before been conferred on any Indian Army unit. This fact alone testifies, if testimony were needed, to the services rendered by the Corps.

"The Memorial which I am about to unveil has been erected by all ranks of the Corps to perpetuate the memory of their comrades who made the great sacrifice for King-Emperor and Country, and of their 563 comrades whose memory we honour to-day, the great majority were killed in action or died of wounds. This Memorial, however, will stand on this spot for all time not only as a token of respect, affection and admiration for those who so unselfishly gave their lives, but as a reminder to the men of this

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and of future generations of their duty which they in their turn must do, and of the example of heroism and self-sacrifice which was set them by the men whose names are inscribed on the Roll of Honour of this Memorial.

"In villages, and in great towns, in Europe, Asia and Africa stand Monuments or memorials, great and small, all testifying to the gallantry of Troops of the King-Emperor in the Great War, all bearing their message to the citizen of to-day and of to-morrow —a message which cannot but instil into the hearts of all a determination to be worthy of those who died that we might live free men, under that flag which flies in every quarter of the globe—a flag which means, for all who live under its shadow, justice and liberty.

"Of those officers and men of the Corps of the Royal Bombay Sappers and Miners, truly it can be said

"Splendid they passed, the
Great surrender made,
Into the light which
Never more shall fade."

"To the glorious memory of 563 officers and men of the Corps of the Royal Bombay Sappers and Miners, I now unveil this Memorial."

Just previous to the actual unveiling, H.E. handed to Subadar-Major Muhammad Din, Bahadur, I.O.M., an Urdu translation of his speech, which the latter read to the whole Corps after the departure of H.E. H.E. then pressed the switch and the flag draping the Memorial fell away. The Roll of Honour was taken from its escort and placed in its position on the Memorial by Subadar-Major Muhammad Din. The Corps then presented arms, while the buglers played the Last Post followed by the Reveillé. After this, wreaths of evergreens were placed round the foot of the Memorial by the Officiating Commandant, the Regimental Sergeant Major, and the senior Indian Officer of each of the three castes enlisted in the Corps. At the conclusion of the Ceremony, H.E. took his departure under a salute from the Guard of Honour. Among others who attended the ceremony were Major-General Sir Edwin Atkinson, K.B.E., C.B., C.M.G., C.I.E., Major-General R. N. Harvey, C.B., C.M.G., .D.S.O., Colonel Commandant A. Rolland, C.B.E., D.S.O., as well as a number of pensioned Indian Officers of the Corps.

The Memorial stands on the Parade Ground about 40 yards back from the centre of the side facing the lines. It was designed by the consulting architect to the Government of Bombay and built almost entirely by men of the Corps. As will be seen from the photographs, it consists of a stone cenotaph; the English inscription on the front face is repeated in Urdu, Gurmukhi and Marathi on the three remaining faces.

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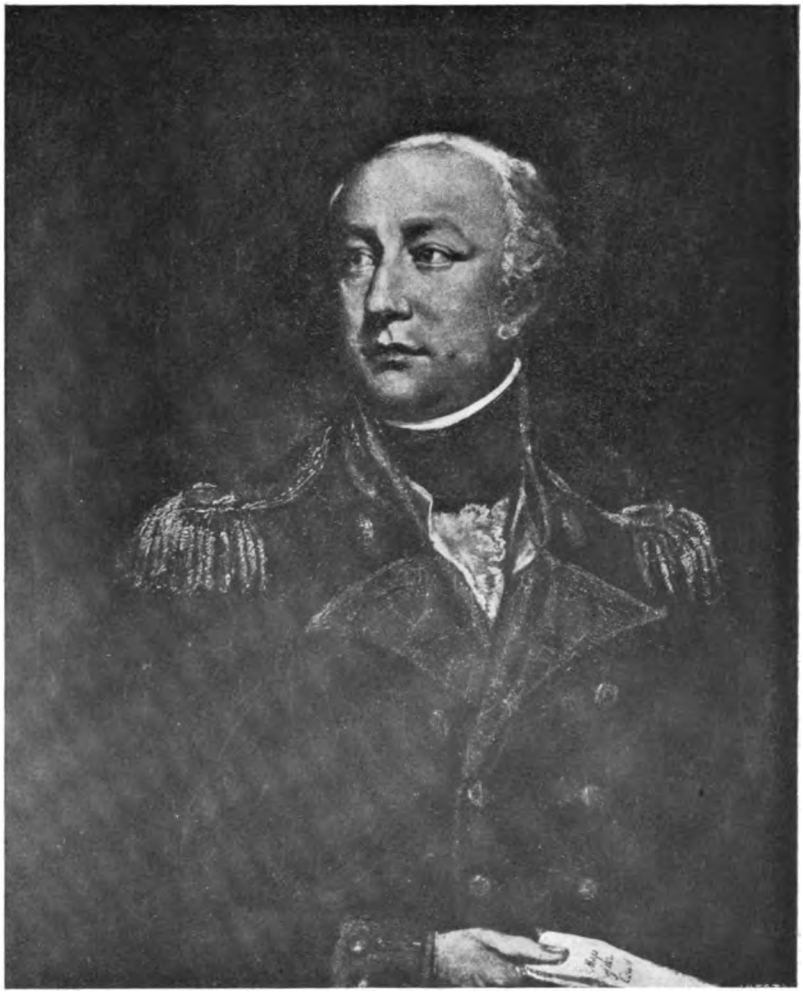

[*Reproduced from Autotype.*]

MAJOR-GENERAL WILLIAM MUDGE, R.A., LL.D., F.R.S.

1762 — 1820.

Director of the Ordnance Survey from 1798.

Lieut.-Governor of the R.M.A., Woolwich, from 1809.

Superintendent of the H.E.I.C's College at Addiscombe from 1810.

From a picture painted by James Northcote, R.A., in 1804.

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THE EARLY YEARS OF THE ORDNANCE SURVEY.

(Continued).

V. The Directorate of William Mudge (Continued).

Colby joins the Survey.—Thomas Colby was born in 1784, and received his commission, as a Second-Lieutenant in the Royal Engineers, on the 21st December, 1801, being then just over 17 years old. His commission is signed by George III and countersigned by Lord Chatham, Master General of His Majesty's Ordnance. A short account of Colby's career will be given later on; meanwhile it is sufficient to say that it is to Colby that the Survey owes its present organization, and to Colby, also, were due most of the methods which were in use for nearly a century. It was, indeed, Colby who eventually gave the Survey its distinctive character. Three weeks after being commissioned he was appointed to the Survey by the following minute, addressed to Major Mudge, from the Chief Engineer's office, Westminster:—

12th January, 1802.

Sir,

I am directed by Lt.-General Morse to acquaint you that Second-Lieutenant Thomas Colby, of the Corps of Royal Engineers, is ordered to put himself under your command to be employed upon the Trigonometrical Survey. . . . . ..

I am Sir,

Your most obedient humble servant,

John Rowley.

Major Mudge, &c., &c.

Colby soon showed his capacity, and, even as a mere lad, he was entrusted by Mudge with a large share of the work. When, in 1809, Mudge was appointed Lieutenant-Governor of the Royal Military Academy, he left the detailed conduct of the operations largely to Colby, who was then aged twenty-five; and still more of the work devolved on Colby when his chief was, in 1810, given the additional appointment of Superintendent of the College at Addiscombe. The arrangement was probably on the whole, a good one. The larger matters remained under Mudge's control, but Mudge seems to have, rightly, left the actual superintendence and almost all personal work to Colby, who was too young to act effectively with the chiefs of the Board of Ordnance. The position was well known to the

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friends of both officers. Thus, Olinthus Gregory, Professor of Mathematics at the R.M.A., writing to Colby shortly after Mudge's death in 1820, says, the Survey " has been for so many years conducted and carried on so entirely by yourself, that I should have thought that the Master General would have settled the appointment the next day." But until 1809 Mudge worked in the field as well as in the office. The relations between the old man and the young were always most friendly; the letters which passed between the two show complete understanding and co-operation.

It is curious that Mudge should have been effectively in charge for the seven years that Williams was nominally the Director; and that, for the last ten years of Mudge's life he should have been obliged, in his turn, by pressure of other duties, to hand over much of the work to Colby.

Progress of the Work, 1800-09.—In the third and last volume of the *Account of the Trigonometrical Survey* will be found a description of the operations from 1800 to 1809. The triangulation was continued with great rapidity, the two 3-ft. theodolites, and one 18-inch theodolite being used. The angles were observed by Mudge, Colby, Woolcot and Gardner.

By the end of 1809 the triangulation of the whole of England and Wales had been completed, except for the counties of Lincoln, Norfolk and Suffolk, and this operation included not only the main, or principal, triangles, but also the secondary triangles required for the "interior " survey.

When tested by the later triangulation the old work of this period stands well as regards the bases, but not so well with respect to the observed angles. It was found that there was an error of about 170 feet in the arc measured between Dunnose and Clifton, a distance of 196 miles; that is to say there was a linear error of about 1 in 6000. This is larger than Mudge expected, for he stated that he thought it unlikely that there was an error of as much as 100 feet, or say 1 in 10,000. But the matter is not now of any importance. It is clear that the work was of ample accuracy for the one-inch map, and it should be understood that the whole triangulation was recast some forty or fifty years later. In fact, the old angles at only six stations were used by Clarke in his reduction of 1858. We need, therefore, only consider Mudge's work with reference to the immediate purpose that he had in view, and for this purpose the work was more than sufficiently exact.

In the year 1806 a base, about 4½ miles long, was measured, by Colby and Woolcot, on Rhuddlan Marsh, near St. Asaph. Clarke, writing in 1858, says, " The extremities of the line were marked, as at Misterton Carr, with blocks of wood, but of these unfortunately every trace has been lost."

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Heights of the Hills.—An interesting feature of the work of these years was the calculation of the heights of about three hundred hills scattered over England and Wales. The "low water mark" was used as the datum, so that the heights are not directly comparable with modern values. It is stated that "in deriving the numbers expressing the heights, the several differences have been mingled together, and the means always taken." The results were fairly accordant; two independent values of the same height differed, as a rule, by some 6 or 7 feet. *Sca Fell* came out 3166; modern value, 3162; but the old value should have some feet taken from it to allow for the difference of datum. *Skiddaw*, old value 3022; new value, 3053. *Cader Idris*, old, 2914; new, 2927. *Leith Hill*, old, 993; new, 965. *The Wrekin*, 1320 and 1335; and so on. Anyway, for the first time, the public had available fairly good values for the heights of many British hills; sufficiently good, no doubt, in most cases, to correct the exaggerations of local patriotism. But none of Mudge's heights remain on the present day maps.

The Account of the Trigonometrical Survey.—The third volume of this account, which brings the operation up to the end of 1809, was published by W. Faden in 1811. It is much to be regretted that no further volumes were issued. After this date the history of the Survey must be sought in memoirs and private letters, and in technical publications, such as the Lough Foyle Base of 1827, the Latitude Observations of 1842-50, and so on.

In later years we come to the official Annual Reports, which were presented to Parliament and published. But these, for a long period of years, became dull and colourless to the last degree. The first of these reports was not issued, moreover, until 1856. So, in order to find out what was really going on from 1810 to that date, we are driven, perhaps, not unwillingly, to study Portlock's Memoir of Colby, Flint's Memoirs of the Mudge Family, and the correspondence, preserved in the Colby collection, between Mudge, Colby and their contemporaries.

Letters from Mudge.—Thirty-three letters, written by Mudge, have been preserved in the Colby collection; and of these all but one are addressed to Colby. The one exception is a letter to Lieutenant-Colonel Hadden, R.A., who was Colby's uncle, (his mother's brother). Hadden was a distinguished soldier who had served in North America. In 1793 he became secretary to the Duke of Richmond, Master General of the Ordnance; he afterwards served as Adjutant-General in Portugal, and, finally, became Surveyor-General of the Ordnance and a Major-General. Mudge's letter to him is dated, Drawing Room, Tower, 14th January, 1802, and runs thus:—

"I send you your copy of the Kent Map, and will transmit others when I obtain a fresh supply, which will be in a day or two.

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Lord Howe I found at the Board on Tuesday. I communicated the wishes of the Master General, as to his presenting me at the Levee, but his Lordship had made an arrangement which called him yesterday out of Town. I therefore made my own way, thro' the aid of the Lord in Waiting, and presented the Map to his Majesty, who, I think, still remains to be informed, that it is *an actual map*, and not a written account similar to the last presented." . . . .

On September 5th, 1804, Mudge writes to Colby from Teignmouth:

DEAR COLBY,

As soon as possible, let the direction of the Meridian be observed. For this purpose, Woolcot and yourself must lay your heads together. Two double Azimuths that agree will be sufficient. [*Then follow technical instructions*]. Your letter of the 27th ultimo came to hand today. Thank you Colby for your attention to the Base of Altitude business; it assures me of your assiduity, and with all the work we have in hand your perseverance will supply the place of my attendance. And farewell, believing me

Ever your friend,

W. MUDGE.

. . . . .In observing the star tell Mr. Woolcot not to lean with his arm, or rest his breast on the Cover of the Instrument. Col. Hadden desires to be remembered to you, and that you would, when you write to your Father, send your letters under cover to him.

In another letter, apparently from the Tower of about the same date, he says:—" 500 Great People have been here to-day . . . . ."

Tower, May 17th, 1805.

DEAR COLBY,

I will immediately procure and send off to Holyhead, an Ephemeris and requisite tables . . . .[*Then follow instructions for the observation of a star at elongation*]. You act very properly in waiting my reply to the question you propose, in regard to the possibility of certain [changes] being introduced into our work from the circumstance you mention. I certainly do think that we should be very guarded in admitting new *succedanea* in our operations. There has been too much of it of late, but the fault was Woolcot's, not yours. If the Karn of Stones, or the heap upon it, be a fair cone, at least tolerably so, on this occasion have recourse to it instead of a P[ole] . . . . . .

Dear Colby,

Ever yours sincerely, W. MUDGE.

Cockington, July 9th, 1805.

MY DEAR COLBY,

. . . . . .Having got *out* of the Isle of Anglesea, get as far *away* from it as possible. Steer off towards Chester. Don't make a practice of going to all the three points of every triangle, if observations made at two of them will be sufficient. Work round spires, staffs on mountains or any other proper objects, that the Survey may get on rapidly.

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. . . . .I shall be back again in 7 or 8 days. I am just now going to Mintern, or Revel's Hill in Dorsetshire. I shall not send Woolcot to you now. . . . Glad I am that I have a man with me, who can think and act as you do. . . . I wish you in all things to consult your own will, convenience and happiness, requiring you only to be punctual in writing me about all you do . . . .

The Irish Military Survey Bill has no reference to us!

There is now a gap in the sequence of letters, and the next one preserved was written six years later. The year 1811 was a trying one for Mudge. He gave evidence before Commissioners that the total expense of the Survey, during the past 20 years, had been somewhat more than £50,000. It would appear that the atmosphere of the Honourable Board was not, at this time, a very friendly one. But Archdeacon Flint quotes a letter from the Horse Guards, expressing admiration for "those exertions and talents, by which that art [of Topography] has in elegance and accuracy been brought in this country, to a degree of perfection surpassing that of any other country in Europe."

At the same time "an order came from the Master General to withhold every map from the public."

On 27th July, 1811, Mudge writes to Colby from Brighton :—

"You will hear with sorrow and with surprise that ten days have elapsed since I requested the Master General and Board permission to put the Account in the hands of Mr. Faden without receiving any answer to my Letter. This silence augurs mischief! . . . .though checked as I am at the Trigonometrical Plough, perhaps it matters but little whether I turn up the Soil or leave it in Sod. I am quite dispirited and dismayed." . . .

In August and September of 1811 Mudge's work was subjected to a Military Enquiry. He writes on the 2nd September :—

. . . "Had it not been for the *Military Commissioners* I should long since have been on the search after you. . . . .See you not the two words, Military Commissioners, aye, see you them not!—I have been before them. I cannot tell whether they imagine me to be a rogue or not, but they deal with me exactly as if they thought so. They gave me not a moment's notice scarcely for preparation, taking me literally at the *ground hop* on my return to Town from Brighton. They examined me in the twofold capacity of Lt.-Governor of the Academy and Director of the Survey. I have my own opinion of their talents, severally and jointly. I believe they thought some great secrets were hidden and that torture would be necessary to find them out. Soon, however, were they undeceived, for I very shortly told them that the day was come which I had long looked forward to with pleasure, and that I appeared before them rather with the hope of being allowed to assist them in their enquiries than as a subject for examination, for that I knew well, without my assistance, their enquiries never could suffice to satisfy the Public or myself. On this

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Principle, therefore, the gentlemen composing the Board have had laid before them an account of every shilling of money expended on the Survey since the year 1791, amounting to something more than £52,000. That is to say, the Engraving, the interior Surveying, the Trigonometrical Survey, travelling, etc., amounts to that sum. From these accounts it will appear that the average expence of the Total Survey since 1800 has been about £4,300 per annum and the average expence of the mere T. Survey, included in that sum, about £1000 per annum, our salaries, with Mr. Woolcot's and Mr. Gardner's, with travelling included. So you see the anonymous author has told a d—d lie in stating that the Expences of the Survey has exceeded £10,000 per annum. I suppose the Commissioners must, and I dare say they will, make some good natured observations in their Report; they will state more particularly that the Engravers have no check on them after the hours of regular work. I care not, however, because I am conscious that, to the best of my abilities, mental and corporeal, I have discharged every trust deputed to me in this undertaking like an honest man.

I devote this month to travelling among the Surveyors, and I shall beg of you to meet me at Chepstow."

Ever in truth and sincerity, if that be not tautology,

Believe me, your sincere,

W. MUDGE.

Another letter on the same subject :—

Royal Arsenal, Woolwich.
October 1st, 1811.

. . .I know not that it would be objectionable to publish it at Charing Cross, so that I can have no scruple to let the contents of my Letter float on the Sea of Chance . . . . The Board first examined me on the score of the Academy, and the examination impressed me with the opinion, which I believe to be true, viz., that they had got at a pretty accurate knowledge of the state of the Establishment at the time I came to it, and what it was at the hour of examination. . . . In respect to the Survey I was examined on all the essentials of the operation, and finally asked the pointed question of its utility and continuation. I did my best to satisfy them in the first point, and gave for my answer in the second, that the Trigonometrical Survey of England being completed, save and except a small part of the eastern side of it, to complete which little time would be required, I thought the Survey of Scotland, in the mere triangular part, would not take more than 5 years, and that it was my intention to commence the Survey of that part of the Kingdom next year—our destination for 1812 is therefore fixed—The *Total* expence of the Trigonometrical Survey itself *ab origine* 1790=21 years, was stated at £21,000. The Commissioners considered this sum as large, and asked if they could be furnished with all the particulars constituting that expence? I told them certainly, and ***instantly*** they had these further sums given, *viz.*:

£25,347 7s. 7d. for the interior Survey, Travelling, &c.
and £7,817 18s. od. for the Engraving. . . . .

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£54,165 5s. 7d. being the total expence, which, divided by 20, the number of years £2208* for a mean annual expence; but the present mean is nearly £4,416 = the present annual expence. I dare to say the Commissioners will animadvert, pretty strongly, on the apparent magnitude of this sum; but everybody I have shown it to thinks the sum a fleabite; in fact so it is a fleabite, and I myself thought it had been more . . . . I am certain they were strongly impressed with an idea of the extreme accuracy of the work, but I think the Commissioners will stab at my plurality of offices. My last moments, whenever they do come, will not be embittered with the recollection of any of my sins of commission or omission as touching the Survey. The Work† is approved of and sells well. All publication of *future* works is stopped."

So the Board of Ordnance, in its wisdom, saw fit to stop the further publication of adequate accounts of the work of the Survey; a prohibition of which the effects remain to this day. For the Annual Reports which were eventually issued (but not till 1856) are poor things compared with the reports issued by other great surveys, and are but meagre outlines of the work accomplished, though they are better than nothing. Mudge, after 1811, had to content himself with nothing. Lord Mulgrave was the Master General responsible.

Mudge, and the Survey, survived the encounter with the Commissioners, and the work went on. On the 9th September, 1813, he writes :—

" I am very desirous that you should immediately read the review of Major Lambton's Papers in the Asiatic Searches, giving an account of his Trigonometrical operations in India, which review is to be found in the last number of the Edinburgh Castigator; it is undoubtedly done by Playfair, who had us in his eye all the way through, and has ended his critique with the strongest compliment that could have been paid to the Surveyors in this country . . . . Mr. Playfair is a man of great natural sagacity and much acquired information.

" You will now hear with great satisfaction the probability of my returning with you to the North next Spring to finish our operations, for my health is much restored, and though I write by the hand of another, yet I am in many respects better than I have been for some years, and this brings in my mind how happy I am to account myself, that Providence has placed to my hand so able and so firm a friend as you are.....

Royal Arsenal,
22nd September, 1813.

DEAR COLBY,

I have written to the Board desiring that orders may be sent to the storekeeper at Fort George to receive the Sector and Apparatus. You, of course, direct your steps due south, and will perhaps arrive at your old

* A slip of Mudge's, it should, of course, be £2708.

† Volume III of the *Account of the Trigonometrical Survey*, published by Faden in 1811.

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quarters in the Tower sometime in the middle of October. You are very much wanted, for what with laying down of points, settling of edges, reconciling differences, and setting out new Work, there is abundant to engage you. Mr. Gardner will, of course, come with you . . . . General Hadden was with me yesterday, and also Mrs. Hadden, after putting Brother Martin into his grave. Poor old Gentleman, 97 years after he was born he bid adieu to this World of tears and repentance, and now lies with the mouldering remains of all the Carpulets in Plumstead Church Yard . . . . The public papers will have made you acquainted with the loss of my poor friend Fletcher,* a loss indeed, both to the Public and to his Family, but this comes of Volunteering and looking plump into the Cannon's Mouth. Collyer fell upon the top of the breach killed, his place was directly supplied by Mr. Marshall, who instantly dropped wounded; the third, Capt. Rhodes, immediately repaired to the spot and was also instantly killed, a fourth then mounted the breach and happily survived; really I think hereafter the Corps of Engineers should be looked upon as belonging to *Undertakers* as well as to Carpenters and Joiners, and have the Death's Head and bones upon their Buttons by way of a *Memento Mori*. It is a nice Corps for Promotion, but excessively selfish, for it has absorbed all that once belonged to the Artillery."

In the same year, 1813, Wordsworth wrote a poem on the subject of one of Mudge's experiences on the mountain of Black Comb in Cumberland. "Written with a slate pencil on a stone, on the side of the Mountain of Black Comb—

Stay, bold Adventurer; rest awhile thy limbs
On this commodious Seat! for much remains
Of hard ascent before thou reach the top
Of this huge Eminence—from blackness named,
And, to far-travelled storms of sea and land,
A favourite spot of tournament and war!

Know . . . .
That on the summit whither thou art bound
A geographic Labourer pitched his tent,
With books supplied and instruments of art,
To measure height and distance; lonely task,
Week after week pursued!

....Once, while there he plied his studious work,
Within that canvas Dwelling, colours, lines,
And the whole surface of the outspread map,
Became invisible . . . . . .total gloom
In which he sate alone, with unclosed eyes
Upon the blinded mountain's silent top!"

* Sir Richard Fletcher, killed on 31st August, 1813, at San Sebastian. He had married Mudge's sister, Elizabeth.

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The Beginnings of the Geological Survey.—Mudge, writing to Colby on the 16th May, 1814, says,

" On Friday I received a letter from Col. Chapman, grounded on a very good and scientific Representation to the Master General, desiring to know whether or not a Mineralogical and Geological Surveyor would not be exceedingly useful to me, as affording means of making those observations in those branches of human knowledge that might help to account for those extraordinary Anomalies which have of late so inconveniently hung round our operations. The Master General at the same time desiring to be informed whether, if such were my opinion, Dr. McCulloch would not be a very good person for the place. My answer was, as you may suppose it was, affirmative all the way through, and I do in consequence expect to have Dr. McCulloch's appointment nominated to me before the present week shall finish its course."

The idea was, that Dr. MacCulloch (as his name is usually spelt), should be able to point out where and what abnormal deflections of the plumbline were likely to occur; with a view to avoiding stations for the zenith sector where large deflections might be expected. The zenith sector observations being required for the determination of the meridian curvatures, which were themselves required in the construction of the one-inch map.

John MacCulloch was born in 1773, in Guernsey, and studied medicine in Edinburgh. In 1811 he gave up his practice and devoted himself to the geological investigation of Scotland. In May, 1814, he was appointed geologist to the Trigonometrical Survey. In 1826 he was instructed by the Treasury to prepare a geological map of Scotland. " This large undertaking was completed in 1834. There were, however, no detailed topographical maps of Scotland available at that time, and MacCulloch had to enter the geological colours on the meagre topographical basis of the Arrowsmith map. MacCulloch's map was published posthumously in 1840."* A competent observer, Mr. J. Jardine, writing to Colby in December, 1819, expresses his astonishment at the extent of MacCulloch's work and its accuracy. " No person but a man of iron like yourself could have gone over such an extent of rugged country with so much minute accuracy."

MacCulloch's death occurred in 1835, and was caused by a carriage accident.

Lyell, in an address to the Geological Society of the 19th February, 1836, says, " The map of Scotland, by Dr. MacCulloch, which has been so long and impatiently expected, is at length on the eve of publication. But at the moment when I can announce this

* Zittel's *History of Geology and Palæontology*, translated by M. Ogilvie-Gordon, p. 113. The writer is indebted to Mr. J. A. Howe, of the Geological Survey, for this reference.

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welcome intelligence, we have to deplore the sudden loss of this distinguished philosopher." Lyell speaks of a want of condensation and clearness in MacCulloch's style and "a disposition to neglect or speak slightingly of the labours of others." MacCulloch seems to have been troubled with continual ill-health, and this made him difficult to get on with. His work, is, however, of importance in the history of geology, and Lyell said that he received more instruction from MacCulloch's labours in geology than he had from those of any then-living geologist.

The rest of the early history of official geology in this country may be briefly summarized. MacCulloch himself wrote *Memoirs to H. M. Treasury respecting a Geological Survey of Scotland*, the forwarding letter being dated July, 28, 1834. These memoirs were published by Arrowsmith after MacCulloch's death. The writer says that the Board of Ordnance gave him originally two principal tasks; one being to discover a mountain more suitable for the determination of the density of the Earth than Schiehallien, and the other the geological investigation of probable attractions of the plumb-bob. There were no accurate maps of Scotland in his day, and he says, with reference to the one-inch Ordnance map of England "It would require but a small geologist indeed to lay down the rocks of any part of England on the Ordnance maps; he is to be envied on whom such a duty may hereafter fall." He also talks about "the geographical surveyors of that splendid work."

In the spring of 1835, the Master General and Board of Ordnance appointed a committee, composed of Lyell, Buckland and Sedgwick, to report upon the desirability of a Geological Survey of England. "The enlightened views of the Board of Ordnance were warmly seconded by the present Chancellor of the Exchequer, and a grant was obtained from the Treasury to defray the additional expense which will be incurred in colouring geologically the Ordnance county maps." But, for some years before this was sanctioned, H. T. De la Beche had been mapping, at his own expense, the geological structure of Devon and Cornwall. He applied to the Government for recognition and assistance, and his application was warmly supported by Colby, who had long encouraged the Ordnance Surveyors to keep a record of geological observations. De la Beche represented that his work would be much more efficiently carried out if joined with the Trigonometrical Survey. The sum allowed for the Geological Survey was £300 a year, most of the expenses still falling on De la Beche. A room was assigned to him for the collection of geological specimens in Craig's Court, Charing Cross—an address once very familiar to R.A. and R.E. officers—and De la Beche was appointed Director of the infant museum—with no salary.

In 1845 the geological staff, which had meanwhile been increased, was transferred from the Board of Ordnance to the office of Woods

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and Forests, and, thereafter, the only connection between the Geological Survey and the Ordnance Survey was that the latter continued to print, colour and publish, the maps of the former. De la Beche remained in charge of the Geological Survey until 1855, when he died, and was succeeded by Sir Roderick Murchison.

The friend and biographer of Sir Roderick, the late Sir Archibald Geikie, who was Director of the Geological Survey from 1881 to 1901, wrote in his recently published autobiography*: "During the first ten years of its existence, [1835-1845], the Geological Survey was a branch of the Board of Ordnance. Its officers wore a dark blue official uniform. But a tight-fitting, well buttoned frock coat could only be an inconvenient garment for the rough scrambling and climbing life of a field-geologist. It was accordingly at once discarded when the Survey in 1845 was placed under the office of Woods and Forests."

One would like to know who insisted upon the dark blue frock coat. It does not seem the sort of thing that Colby was likely to do. Some of the brass buttons that adorned the coat, bearing a device of crossed hammers, are still in existence.

Don Rodriguez.—There is a wearisome small business which must be recorded, because it occupied a good deal of Mudge's time and exercised his patience, but in itself was a matter of little importance. Don J. Rodriguez was permitted to publish, in the *Philosophical Transactions* of 1812, a paper in which he explained the anomalies in Mudge's arc from Dunnose to Clifton as being caused by errors in the latitudes derived from Ramsden's zenith sector. Mudge was convinced that this was not the true explanation. But some scientific men accepted the Don's view and Mudge was naturally concerned to defend the accuracy of his work. In his letter to Colby of the 16th May, 1814, he writes:—"I should have derived infinite satisfaction from the Zenith Sector being this year used instead of the Circular Instrument, and am sure I cannot see why it should not be so used, for I should in that case be enabled the sooner to put up the Zenith Sector on Arbury Hill, which I have promised to do, and certainly will do, not indeed to please Don Rodriguez, for he at length has given up, but to vindicate the memory of Ramsden and ourselves. The Reviewers, you will find, have, I am sure, without my knowing anything about it, made their *amende honorable* and the Honorable Society are likewise concerned that they have given any Countenance to Don Rodriguez."

It does not appear that Arbury Hill was ever, as a fact, revisited for the purpose. But there are three stations in the triangulation of the United Kingdom at which observations for latitude were taken

* *A Long Life's Work.* Sir Archibald Geikie, O.M., K.C.B., F.R.S. p. 47.

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with Ramsden's zenith sector, and forty years afterwards with Airy's zenith sector. These three stations are: Dunnose, Cowhythe and Balta. The difference between the resulting latitudes were found to be: 0".01, 0".11, and 0".09—an ample vindication of the excellence of Ramsden's instrument. And there we may leave the matter.

The Work of the Survey from 1810 to 1820.—During these years the triangulation was pushed on into Scotland, the observations being made by Colby and Gardner. Thus we find that, in 1814, Colby observed from 10 stations in Scotland; in the latter part of 1815 the observations were chiefly carried out by Gardner, because Colby was then called to the Tower. There are records of the Scottish triangulation being carried on by these two in the years 1816 to 1819 inclusive.

The zenith sector was set up at Kellie Law in 1813, at Cowhythe in the same year, and at Balta in 1817, Colby and Gardner being the observers.

In 1817, also, Colby and Gardner measured a base at Belhelvie, near Aberdeen. Its length was 26,515.65 feet of Ramsden's scale, or 26517.53 feet of the final Ordnance standard (O_1). As tested by the connection with the later triangulation, reduced by Clarke, the discrepancy was about 1 in 110,000. This base was measured with Ramsden's two 100-ft. chains and one 50-ft. chain.

The detail survey went on in England. "Surveyors belonging to the corps of Surveyors and Draughtsmen were now employed in various parts of the country, by permission of the Chief Engineer (Inspector General of Fortifications), who was the official head of the corps, and they received, besides their military pay as warrant officers, 32s. 6d. per square mile, for all the work they surveyed and plotted on a scale of two inches to the mile. These plots were reduced at the Map Office to plans on a scale of one inch to a mile and traces from these prepared for the use of the engravers."* Before Mudge's death in April, 1820, substantial progress had been made in the production of the one-inch map. 37 sheets had been printed, with regular sheet-lines, ignoring the county boundaries. The sheets varied in length from east to west, the largest being 35 inches long; from north to south they measured 23 inches. The area covered was the whole of the South of England, up to a line running roughly through Bath, Oxford, Hertford and Ipswich. The sheet covering Pembrokeshire was also printed. And of course, many sheets were in the hands of the engravers.

* *Memoirs of Major-General Colby.* By Lt.-Col. Portlock, R.E., F.R.S.

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Some more letters from Mudge:—

Royal Arsenal,
16th May, 1814.

We have had so much trouble here with shewing the lions to one Duchess, that the trouble to shew them to two Emperors and one King, if it be determined by the Rules of Common Arithmetic, I look for it as certain that Bedlam will be well stocked.

Royal Arsenal,
14th August, 1815.

. . .of Dr. McCulloch I know nothing and have in fact heard as little as I know—your sentiments on our Union with his proceedings are precisely the same as mine. Mr. Hyett has completed his second Survey of the St. Alban's District, and certainly the result would augur that we have blamed him beyond his deserts. Mr. Yeakell seems to break [up] with great rapidity both as his strength of Eye and general health is concerned. . . . I find it necessary to look very close into his work. . . .

Royal Arsenal,
September 21st, 1815.

On account of the advanced season of the year and still more on account of my long continued indisposition . . I beg you will *immediately* close your operations and return to London.

Royal Arsenal,
27th January, 1816.

. . . .When I get Mr. Crocker's Edge, Mr. Budgen's plan, and Mr. Stanley's plan, the whole should be sent to the office, or rather taken there by myself that a fair view of the whole transaction may be laid before the General [*i.e.*, the I.G.F.].

5th February, 1816.

. . . .I want to cut off the surveying attendants on the Surveyors and that as quickly as possible.

29th February, 1816.

I . . .was informed that the Austrian Arch Dukes wanted to see everything connected with the Survey, therefore let Mr. Yeakel look out all such plans as it may be proper to show them not neglecting the Isle of Wight and Kent plans. . . . Tomorrow I go to Addiscombe on particular business.

Royal Military Academy,
2nd September, 1816.

. . .It is my desire not to have more of the public money in my Hands than is actually wanted. . . I believe . . that I have more difficulties thrown in my way as to the progress of the map making by Ignorance, Avarice, and Cupidity than you have by the intervention of Mountains, Morasses with all the local difficulties peculiar to Scotland put together. . . It will, however, please you in understanding that the Work is most highly approved of and esteemed as exceedingly accurate.

10th September, 1816.

I do not imagine under all the difficulties which seem to attend the Northern Survey that the Business of another station can be achieved this year, and if so the conclusion of your operations will be found on Cairnsmuir.

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Royal Arsenal,
24th December, 1816.

I wrote M. Biot yesterday, and sent him a sketch of the Triangles Mr. Gardner did for me with some but not many observations touching the best way of proceeding next Year. I dare say I shall hear from him in reply and now I beg you will be so good as to get Mr. Gardner to do for me as quickly as he possibly can another Tracing of the Triangles with the Meridian running up from Dunnose as well as Black Down, and I shall be very glad if I can be supplied with it this week. I came downstairs for the first time to-Day consoling myself with my good luck in not being prisoner to my Bedroom longer than I have been. . . I have sent my son [Lieut. Richard Mudge] to Shrewsbury to look after Mr. Stevens' Work.

West European Arc of Meridian.—In the year 1816 the project of extending northwards the European Arc of Meridian, which already stretched the whole length of France, and had been continued into Spain, was discussed on both sides of the Channel. Roy's cross-Channel connection amply sufficed for the purpose of joining the two national surveys, and the chief matter which required decision was the selection of the terminal point of the arc in Great Britain. At first the French were inclined to support Yarmouth (in Norfolk), as suited for the purpose; but eventually better counsels prevailed, and the obvious scheme of using the triangulation of Great Britain to its fullest extent was adopted, and the terminal point was fixed in the Shetland Islands.

Sometime early in 1816, Arago wrote thus to Mudge:—

" La lettre que vous m'avez fait l'honneur de m'écrire a beaucoup ajouté aux regrèts que j'avais déjà de ne vous avoir pas été présenté le jour de mon voyage à Woolwich. J'avais le plus grand désir de m'entretenir avec vous de la belle entreprise que vous dirigez avec tout de succès . . . . Le seul moyen de me dédommager sera, Monsieur, de me permettre de vous communiquer par ecrit quelques idées qui ont été souvant discutées dans le Bureau de longitudes de Paris, sur la liaison qu'on peut établir entre vos mesures et celles que nous avons executées en France et en Espagne.

On the 19th October, 1816, Arago again writes to Mudge:—

J'ai reçu la lettre que vous m'avez fait l'honneur de m'écrire et dès aujourd'hui je vais mettre votre obligeance à contribution; je vous demanderais Si Yarmouth est déjà lié a la chaine principale de vos triangles et s'il est entré dans votre plan de faire mesurer la latitude de cette station avec assez de soin pour qu'on puisse en faire le point de départ d'une Ligne méridienne qui se terminerait à Formentera. M. Laplace, qui m'a chargé de vous presenter des complimens, tiendrait beaucoup a l'exécution de ce projet; il verrait dans l'arc compris entre Yarmouth et Formentera, le moyen de trouver avec une extrême précision la Valeur D'un dégrée de Latitude pour le 45me dégré. Cette opération aurait cet avantage précieux d'appartenir également a l'Angleterre et à la France et servirait, peut-être, un jour à établir un systeme uniforme de Poids et Mesures."

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Arago goes on to say that the Institute had elected Mudge "un de ses correspondans dans la Section d'Astronomie." Laplace, on the 21st March, 1817, made a speech in the Chambre des Pairs on the subject of the measurement of the West European Arc; in this speech he alluded to Mudge as follows: Le Colonel Mudge, qui lève avec autant d'habilite que de zèle les plans de l'Angleterre et de l'Ecosse, doit se réunir aux savants français et concourir avec eux au prolongement de notre méridienne.

Jean Baptiste Biot was the Frenchman selected to work with Mudge and Colby; Arago, unfortunately, was not able to come over to England at a suitable time. Biot (1774-1862), was a friend of Laplace and Arago, a distinguished member of the French Institute, and a man of all-round attainments. But he and Colby did not manage to hit it off. Biot was ten years older than Colby, and it is possible that he did not realise that the latter had for many years been in effective charge of the operations of the survey. Biot arrived in England in May 1817, and was hospitably received. On the 20th of that month, Mudge writes:—"I have been travelling in a chaise with M. Biot, who speaks English as imperfectly as I do French." Mudge had resolved to take charge of the work, but alas! ill-health prevented his getting further than Edinburgh. He writes from Leith on the 7th June, 1817, to Colby, who was then at Aberdeen:—

"I came here with M. Biot upwards of a fortnight since and have been busily occupied in erecting an observatory, preparing for the clock, and adjusting the Circle of repetition... I am chained up here something like a wild beast against my will, finding it impossible to leave M. Biot, whom I perceive to be a very able man and a very diligent observer. ... Dr. Gregory will come out for the holidays and perhaps be at Aberdeen towards the end of the month. Mr. Thomas, Commander of H.M.B. Investigator, goes round to Aberdeen tomorrow to have an interview with you."

Ultimately, the scheme agreed to was, that Colby, Gregory and Gardner should take Ramsden's zenith sector to some station in the Shetland Islands and observe for latitude; that Biot, accompanied by Richard Mudge, should observe a latitude with the French repeating instrument at the same station, and should also take pendulum observations for the determination of gravity; that the British survey should connect the Shetland station with the British triangulation, through the Orkneys and Foula.

A letter from Laplace to Mudge has been preserved. It runs as follows:—

Paris, le 4 juillet, 1817.

MONSIEUR,

Je commence par vous remercier de la bienveillance avec laquelle vous avez acceuilli mon idée de joindre Yarmouth à la méridienne de France, en voulant bien coöperer vous même à cette jonction.

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Mais je vois par votre lettre qu'en étendent jusqu'aux isles Shetland vos operations, et vous rapprochant ainsi de cette meridienne, vous croyez que l'on peut sans erreur sensible joindre votre arc de meridien au notre et qu'alors la station de Yarmouth devient inutile ; je pense entierement comme vous, Monsieur, et je suis persuadé que l'extension de l'arc du meridien jusqu'au soixantième dégré de latitude est plus que suffisante pour compenser l'inconvenant qui pourrait resulter d'une petite dissemblance des meridiens aussi voisins. . . .

Je me felicite, Monsieur, de l'occasion que m'offre cette circonstance pour vous témoigner toute ma reconnaissance, et l'estime particulière que vos travaux importans m'ont depuis longtemps inspirée.

Well, the execution of this scheme was largely spoilt by the fact that Colby and Biot could not agree ; Mudge not being there to take charge and compose differences. Portlock says that " Dr. Gregory attached himself to Captain Colby ; and whilst the latter disliked and distrusted Biot, he, Biot, detested Dr. Gregory. Don Rodriguez, who had been so severely attacked by Dr. Gregory, had been the associate and friend of Biot in the triangulation of France and Spain." Richard Mudge in after years said that " it was fated that an eternal frost should separate Colby and Biot."

In the end Colby set up his instruments at Balta, and Biot his instruments on Unst. Mudge writes to Colby, " One great disadvantage attending your removal from M. Biot is that a comparison cannot be made between the results of observations. . . . . with the sector and circle of repetition ; this is a very great misfortune " ; and again, " I have never ceased to deplore, with the keenest recollection, the happiness that I thought before me nipped in the bud, and I sent home, as it were, invalided."

There is no need to go into the details of the operations ; they must not be looked upon as wasted, but as somewhat injured by the want of co-operation. The coolness between Colby and Biot never extended to Arago, nor did it affect further co-operation. In November, 1817, Arago and Humboldt, accompanied by Biot, came to England with two pendulums, which were swung at Greenwich in the presence of Pond, the Astronomer Royal. Arago, Humboldt, Biot and Colby all met at Mudge's house in the Arsenal during the same month. Late in 1818, Mudge and Colby took Ramsden's sector to Dunkirk and observed a latitude with it, at the request of Arago and Biot ; but " it is certain that the desire of Colonel Mudge, to bring the sector and repeating circle into direct comparison with each other, was not even gratified at Dunkirk." No blame, with regard to the Shetland affair, was ever attached, by anyone, to Mudge, who remained on friendly terms with all concerned.

Let us end this story of the Shetland work on a more cheerful note :—

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Captain A. Thomas, R.N., to Colby, H.M.B. Investigator, Balta Sound,
26th August, 1817.

"I have sent you by the Jolly Boat two gallons of rum and thirty pounds of Ship Biscuit, now in return you will be so good as to send me on board the same man that was on Yell and Fetlar with me, and to-morrow evening the staff will be on Ronas Hill; and should there be any westing in the wind the day after tomorrow, the staff will be on Faul Isle. . ."

Progress of the Work from 1818 to 1820.

Mudge to Colby, April 25, 1818.

"I have a great deal to do one way or the other, so that I shall not be at the Tower until towards the end of the week, but if you will take a run down we can arrange anything that may appear pressing to you. I attended Council of Royal Society on Thursday, on business closely connected with the Survey, of which I can say nothing more at present excepting that the Pendulum is to be carried along our arch under Captain Kater."

Royal Arsenal, Woolwich,
1st May, 1818.

. . ." I was yesterday at the Committee Somerset House, when it was determined that Captain Kater should go on the Meridional Line from Dunnose to Shetland, visiting the two extremities of the Arc and three intermediate stations, and Edinburgh one of them."

Royal Military Academy,
1st September, 1818.

"The account you give of your operations is very satisfactory, and we have another proof, if another proof were wanted, of your zeal and activity. When the state of the Work shall be known to the public they will have a just means of estimating your talents which will receive their deserved reward. The Frome sheet is struck off with the Hills finished. I have been all over that quarter with the Map in my Hand and find the work excellently done. Sir Rd. Hoare, to whom I gave a proof for correction, is delighted with the work and particularly with the antiquities, to which all the persons employed on the Survey of that Quarter have paid particular attention. . . . . The Admiralty, with Mr. Croker, took down the Hampshire Survey when they settled in the South the new Telegraph line. Mr. Croker told Captain Hurd that without it they could have done nothing. Faden also says that the reputation of the Work increases daily."

In the same letter he points out to Colby the necessity of accepting the French offer to take the sector to Dunkirk.

"I do say that tho' you have no reason whatever to be pleased with Biot, and God knows I have just as little, yet I trust you will see with me the actual necessity of our concluding the work of this year in France; I feel that by so doing I shall conclude my labours honourably. . . . Captain Thomas in the Investigator will take us to Dunkirk."

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14th September, 1818.

..." I am to-morrow to be at the Admiralty with Mr. Croker, and am truly happy in finding we are firmly supported in that quarter. . . . The work of reduction, the deadly work of reduction, is going on swimmingly. [The Ordnance estimates were being reduced and the Artillery cut down]. . . . I am, thank God, perfectly well and just off a journey of 260 miles. P.S.—Mr. Gardner must go over with us."

Royal Arsenal,
21st February, 1819.

" The Duke [of Wellington] has postponed for a little time any consideration of the Scotch Survey, but proposed, when his present business is off his hands, to see whether it cannot be carried on less expensively than the way we propose." The Duke had also complained of imperfections in the one-inch sheet containing Strathfieldsaye and Mudge says, " It is my intention to battle this matter inch by inch. To all appearances I shall

See a great deal more of
His Grace than will be
pleasing.

I am quite depressed under all these considerations and mean without delay to collate all the Field Work in hand, that the vessel may be under proper Trim when the Storm comes on. Of the little time I have before me I must make all the use I can. My opinion is that the Quarter-Master-General's Department and Arrowsmiths are at the bottom of the whole of it."

That is the last letter preserved in the Colby collection from this old chief of the Survey. He had now not much more than a year to live. He died, as stated above, on the 17th April, 1820.

Robert Dawson, who had worked under Mudge since 1802, and knew him well, wrote to Colby on hearing the news :—

" Alas ! the connection of 18 years is dissolved and we are left in sorrow and reflection. The General's kind and amiable disposition, his mildness of temper, gentleness of command, and many marks of attachment and regard given to me particularly, and evidently always ready for his Friends, have created and nourished a Love for him in my heart, which will ever be the first impulse with which I shall cherish his memory."

Portlock, who was a cadet when Mudge was Lieut-Governor of the R.M. Academy, says in his memoir, " The present writer, when at the Academy, enjoyed the occasional privilege of visiting at his house, and whilst participating in the friendly hospitality which he bestowed upon his young friends, and which was always distinguished by a warmth and simplicity which made them feel quite at home, even with the Lieutenant-Governor, had ample opportunity of witnessing and appreciating that never-ceasing enthusiasm for his favourite science which he felt in his own heart, and desired on every occasion to instil into the minds and hearts of his young guests."

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QUANTITY OF WATER IN CONCRETE

The January, 1925, issue of *Concrete and Constructional Engineering* calls attention to the fact, that the strength of concrete depends as much on the quantity of water as it does on the quantity of cement. Too little water in concrete has the effect that the particles of sand and ballast are not sufficiently well lubricated to slip into place in such a way as to get a concrete of maximum density. The particles remain touching on points, with considerable air voids, and form a relatively porous concrete, and if the lack of water is carried to excess there may even be insufficient water to develop the full chemical action of which the cement is capable. In the same way an excess of water evaporates, and its place is taken by air, so that once more the concrete is left relatively porous with the particles touching on points instead of over their whole area. It is quite clear that the densest concrete will be the strongest, and this has been proved by numerous experiments. We print below a table prepared by Dr. Oscar Faber, O.B.E., D.Sc., M.Inst. C.E., showing the quantity of water which he uses for different concretes. He gives the following formula:—"Take 28 per cent. by weight of the cement and add 4 per cent. by weight of the sand and ballast. This gives the weight of water (at 10 lbs. to the gallon) required to give a good working mix when the sand and ballast are dry and are of non-absorbent materials." The extra amount of water required for absorbent materials is best found by weighing, say, 8 c.f., of the material both dry and after it has been thoroughly soaked in water. The difference in weight should be added to the amount calculated for non-absorbent materials.

QUANTITY OF WATER TO GIVE BEST RESULTS FOR REINFORCED CONCRETE WITH DRY NON-ABSORBENT MATERIALS.

Mix.	Weight of Materials. Lb. per bag of cement.			Volume of Materials. Cu. ft. per bag of cement.			Lb. per bag of cement.			Water per bag of cemnt. Galls.	Water per cu yd. of sand and ballast
	Cement	Sand	Ballast.	Cemnt.	Sand.	Ballast.	28% Cement	4% Sand and Ballast	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
1, 4, 8	200	800	1.600	2.22	8.88	17.77	56	96	152	15.2	15.4
1, 3, 6	200	600	1.200	2.22	6.66	13.33	56	72	128	12.8	17.3
1, 2, 4	200	400	800	2.22	4.44	8.88	56	48	104	10.4	21.1
1, 1½, 3	200	300	600	2.22	3.33	6.66	56	36	92	9.2	24.9
1, 1, 2	200	200	400	2.22	2.22	4.44	56	24	80	8.0	32.4

NOTES.

(1) With absorbent materials, add enough water to provide for full absorption.
(2) When materials are wet, reduce water, but not below that quantity given in Column 8.
(3) Cement, sand, and ballast are taken as weighing 90 lb. per cu. ft.
(4) Cement should always be measured by weight.

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THE CHEMICAL WEAPON.

Précis of an Article by "Talin" in *Voina i Mir*, No. 13.

By LIEUT.-COLONEL A. H. BELL, D.S.O., O.B.E., R.E.

The Editor, M. Kolossovski, in a short preface, writes — A characteristic of modern military literature is the rare and grudging discussion allotted to the most important and essential questions. All nations are secretly and silently preparing tactical and technical surprises for their future enemies. The fact that the author of the article is a man of deep erudition, with a wide experience of war and a thorough knowledge of facts, makes his article of considerable value both from a scientific and a practical point of view.

If the war had continued till 1919, by which time the mass production of gas would have been developed and gas bombs would have been used by aircraft, the whole aspect of affairs would have been completely changed. As it is, many people are sceptical about the extensive use of poison gas, and think that its use hitherto has not justified expectations. The war of the future will be as different from the last, as the latter was from the Crusades. The characteristic of the new weapon is the extensiveness of its action as compared to the linear action of ordinary projectiles. The power of this new weapon depends on the quantities in which it can be produced. There have been many fantastic rumours about discoveries of new gases possessing the most improbable qualities, such, for example, as Lewisite, yet when it was tested in European laboratories, it proved to be by no means so terrible as Americans had made out. Even if the ideal war gas were discovered, an antidote to it would surely be found, as it has been to other gases. At the present time there is a defence against all war gases. Modern gas-masks possess powerful absorbers which retain all poison gas, partly by mechanical means, partly by the aid of chemical reactions. But against the use of gases in large quantities this form of defence is insufficient, as the duration of its effectiveness is limited. A zone 50-70 kilometres wide poisoned with yperite* is almost impassible to a soldier even though equipped with a gas mask

* Yperite is β,β^1 dichlor diethyl sulphide $(C H_2 Cl C H_2)_2 S$, or mustard gas.

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and anti-yperite clothing. A man may have to live in such an area from two to four days, but the ordinary absorber is efficient for several hours only; all water and food would be poisoned, horses and transport animals would suffer in an even greater degree than man, moreover, during marches defence against aircraft would be necessary. Only gas-proof trains and tanks could move over the area in safety.

A saturation of one part of air by a millionth part of yperite is sufficiently strong for military purposes. On this basis about seven tons of yperite would be required to saturate an area of 50 sq. kilometres to a height of 20 metres. Germany, at the end of the war, using the complicated method of Meyer, was producing 1,000 tons of yperite per month. America, using Gouthrie's perfected method, will be able to turn out 300 tons per day. The quantity of lachrimatory gas required for infecting large areas would be considerably less, as a weaker mixture is effective.

In the late war poison gas did not occupy a dominating position because countries were not in a position to use it in large quantities and because the means of spreading it were primitive. The use of gas cylinders was a clumsy method, which was completely abandoned towards the end of the war. It was liable to easy discovery by the enemy, was dependent on winds, and could not be used in connection with persistent gases, which are the most valuable from the military point of view. In future, the use of portable reservoirs of poison gas will be a possibility, such as poison candles, which can be made to any dimensions. They consist of metal envelopes of any form, usually cylindrical, filled with a compressed mixture of any easily inflammable material, such as smokeless powder and one of the arsenic compounds. They give out thick clouds of poisonous smoke. Chemical fougasses will be much used; by their means it will be possible to infect evenly and economically large tracts of deserted territory. Various types of chemical machines will be employed for poisoning abandoned trenches and buildings.

Artillery will use chemical shells almost exclusively. At the end of the war 50-60 per cent. of German shells were filled with chemicals. Most of the gases used will be persistent, such as yperite, lewisite, various arsenic compounds and several kinds of lachrimatory gas.

Chemical shells filled with persistent gases will have the bursting properties of common shell; the action of yperite is much increased when forming part of the charge of a shell. There will be no sense in using ordinary common shell or shrapnel, as chemical shell will combine the ordinary bursting effect with poisonous action. In shrapnel the chemical materials will fill the interstices between the balls. Poison gas will be used by all types of combatants, tanks will use smoke as screens; the Navy will use smoke and

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also poisonous gases, which will penetrate through the ventilating system of a vessel and choke the crew.

In all modern armies special gas and bomb-throwing units have been introduced, with special gas-throwing weapons, such as Stokes mortars; in the future war portable projectors will play a large part.

But poison gas will be most frequently and effectively employed from aircraft. Aeroplanes carrying loads of five to ten tons will bombard areas deep in the enemy's rear. The aero-chemical weapon annihilates all the old conceptions of war. The front used to be looked upon as defending what lay behind; all efforts of the enemy were directed towards the breaking of this protective line. Now-a-days the front line will have scarcely any significance. The limits of the battlefield will be extended indefinitely, depending only on the range of aeroplanes. A clear distinction between the army and the peaceful inhabitants will disappear, as every citizen will be under the threat of attack. Poison gas will be the principal weapon of attack for aeroplanes against the army, the fleet and the civil population, as the value of the results will be greater than those obtainable by any other form of load. In open places the effect of gas lasts from two to ten days, and in towns from six to thirty days. According to calculations a two ton yperite bomb will affect an area of 140,000 square metres. When it is required to make large areas of land impassable, in order, for example, to cut off the retreat of the enemy, to defend the flanks, or to prevent pursuit, aeroplanes will scatter bombs of small calibre, according to a pre-arranged plan, a certain number of bombs to a certain area. For such purposes persistent gases only would be used.

The country most advantageously situated for chemical warfare is that with a highly developed chemical industry, large cadres of chemical personnel and up-to-date aviation factories. From this point of view, Germany had a crushing superiority in the last war, but was unable to make use of her advantages owing to the strategical, tactical and technical mistakes she made in the use of gas. Her chemical industry appears to be now based on an *Interessen-Gemenischaft* a trust embodying the whole of the dye companies. The United States towards the end of the war developed their industry with great energy. In the Edgewood Arsenal a whole war-chemical town grew up. In spite of the Washington Conference, this arsenal is still fully equipped and ready—a fact which the Americans make no attempt to conceal. Very shortly after the declaration of war the Edgewood Arsenal could produce 100 tons of yperite per day—using all their factories probably 300 tons a day could now be produced—whereas at the end of the war Germany could produce only 40 tons per day of yperite and 3,000 tons per month of gases of all kinds. But the

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chemical activity of America is not confined to yperite. In the event of mobilisation there would come under the immediate control of the Edgewood Arsenal a number of important chemical factories, such as the Electro-Chemical Co., Oldbury (phosgene); Midland factories (tear gas); Charleston W. factories (raw material for yperite); factories in Buffalo (yperite), Croyland (lewisite, arsenic compounds); Kingsport (tear gas); Stamford (chloropicrin); Hastings-on-Hudson (yperite), and so on. The production of poison gas in the United States would reach fantastic figures.

Serious steps are being taken in England, but with far less success than in America. Research work of a high order is being carried on, and great success has been obtained in investigating the qualities of yperite and in the methods of producing it. One such process has been the obtaining by Gouthrie's method of a stable form of yperite approximating in purity to that obtained by the much more complicated German process (Meyer's). As is well known the Germans were unable to turn out sufficient yperite to keep the front supplied. The allies produced yperite by a much simpler process, the action of ethylene on chloric sulphur. The advantages of the German production were that the yperite was considerably cleaner, more powerful, more difficult to detect, being almost without smell, and far more stable. The resources of England generally are a long way behind those of America, her dye industries being in a decadent condition, notwithstanding subsidies from the Government.

A new war-chemical star is rising on the European horizon—France. Before the war her chemical industries were weak, but now having confiscated the German chemical factories in Alsace and made use of a number of chemical secrets obtained as a result of control, she can consider herself the strongest war chemical power on the Continent. Her lack of experienced chemical personnel is made up for by the work of foreign chemists. The chief organising centre is the *Compagnie naturale des matières colorantes et produits chimiques*, with factories at Villers St. Paul and at Oisel. To this company are united the *Compagnie Parisienne de couleur d'aniline* and *Manufacture Lyonnaise de matières colorantes*. Another large French chemical centre is *Société anonyme de matières colorantes et produits chimiques de Saint-Denis*, with a capital of 60 million francs. Others are *Société Alsacienne de produits chimiques*, and *Société chimique de la grande Paroisse*. These factories are already in a position to satisfy 80 per cent. of the French demands in dyes, and in the event of war would be converted into centres for the preparation of poison gas.

The comparatively inconsiderable production of poison gas in the late war is partly explained by the lack of means for utilising it. There were times when there were not sufficient shells available

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for filling; the use on a large scale of gas projectors, chemical fougasses, poison candles and huge aeroplane bombs will completely change this aspect of affairs. It will no longer be necessary to scatter whole mines of expensive metal over the battlefield, thousands of tons of poison gas will be distributed by much cheaper methods.

The most important materials required for the production of poison gas are chlorine, bromine, arsenic and sulphur. Chlorine is a property of all the chief poison gases: phosgene, superpalite, chloropicrin, yperite, lewisite. Peace production is much smaller than war requirements; more extensive uses for chlorine in peace time are being sought; experiments are being made in the use of chlorine for the production of cellulose, and if these are successful the question of the use of the surplus chlorine would be solved. Bromine enters into the composition of the majority of lachrimatory gases, but most countries are entirely deficient of the means of obtaining it. To get bromine from the ashes of seaweeds or from the water of salt lakes is a complicated and expensive process. Arsenic was not used in poison gas before 1917, but in the last part of the war, first aliphatic and then aromatic arsenics were in use. The latter can be reduced to a particulate state by means of a strong bursting charge, and possess greater power of penetration through the filter of a gas mask than the aliphatic.

Sulphur is a component part of the most important war gas, yperite. All countries are trying to improve the mass production of yperite in case of war, but most of them are not in the fortunate position of Italy and the United States. Owing to a lack of sulphur Germany was unable to produce yperite in the quantities desired.

It is unlikely that there will be a wide use of cyanide compounds in the next war, as experience has not given positive results.

Chemical and dye industries as organised in peace time are far from satisfying military demands in explosives and poison gases; only a few of the four or five hundred materials produced in dye factories are of value for military purposes. In France in 1922 the year's production of dyes hardly amounted to 8,000 tons, whilst during the war France produced about 25,000 tons of poison gas. Germany used to produce 125,000 tons of dyes per year.

For defence against gas careful preparation of all inhabited points and of the whole population is indispensable in view of the use of long distance aeroplane bombers and gas sprinklers and of huge dirigibles capable of transporting tons of poison gas at a time. The problem is two-fold—individual defence and collective defence. As regards the first, anti-gas methods have been evolved on much the same lines in all countries. In the perfect gas mask the following points are aimed at:—

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(*a*) Reduction of the harmful space (that between the skin and the material of the mask in which part of the carbonic acid exhaled is retained).
(*b*) Increase of field of vision.
(*c*) Firm adherence to the face.
(*d*) Lightness.
(*e*) Impermeability to all kinds of poison gas.
(*f*) Reliable valves.
(*g*) Easiness of putting on.

The most important part of the mask is the absorber which is enclosed in a respiratory box (container). It usually consists of three parts, specially prepared charcoal, some chemically active material, such as hyposulphite of soda or permanganate of potash, and a filter (generally made of felt). The charcoal absorbs nearly all the poison, the chemical reacts on the remains of the gas, the filter serves to retain the smoke, *i.e.*, the fine solid particles which pass through the first two parts of the absorber. Not all " smoke " can be stopped by the filter; absorbers must be perfected so as to be of universal application, but the contents must not be so dense as to be an obstacle to breathing.

In addition to masks, anti-gas clothes are necessary to protect the skin from the action of lewisite and yperite, and wearing them involves loss of efficiency in the soldier. In the last war the gases used were mostly of volatile varieties; persistent gases which will be used in future wars will cause gas masks to wear out much more quickly. Moreover, large numbers of civilians must be provided with them, so that the numbers to be manufactured will run into hundreds of millions. Gas refuges, provided with filtering and ventilating systems, were constructed during the last war, but had the disadvantage of being immobile. In the future wars gas refuges in the form of folding tents, made of impermeable material and provided with ventilators and filters will be used. The latter can be improvised from earth or sawdust saturated with lubricating oil or other sticky liquid.

Gas attacks will for the most part be directed on large towns, industrial centres, railway junctions, harbours, fortresses, etc. It must not be supposed that as soon as war is declared all the large towns will be at once destroyed and the inhabitants poisoned, active defence by aeroplanes would beat off an attack for a considerable time, nevertheless it must be admitted that in modern war the inhabited industrial centres will be under the immediate threat of destruction and poisoning. Anti-gas defence must, therefore, be employed not only at the front, but throughout the country. Every person immediately necessary to the Army (and after them the remaining inhabitants) must be supplied with

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individual means of defence. Gas refuges must be ready on a large scale. The supply of food and ammunition, etc., to the Army will have to be specially safeguarded, trains will have to be provided with ventilating and filtering arrangements. Individual protective measures could not be used by young children and old people, nor by invalids with weak respiration; this mass of people would be defenceless unless anti-gas buildings were prepared for them beforehand. In future any large building it is proposed to construct in a town liable to attack, will have to be regarded from a new point of view, that of suitability for use as a gas refuge. A system of neutralisation of poison gas by anti-gas liquids will have to be arranged; oxidisers, chloride of lime and permanganate of potash are the most useful. The expenditure will be very great, as 20 kilograms of chloride of lime are required to neutralise one kilogram of yperite. Mechanical means will also be used, such as spreading charcoal or ashes in the streets, lighting bonfires, and by small explosives.

To sum up: "In view of the mass production of poison gas and the perfected technique of aviation, in the war of the future every citizen will become a soldier and every foot of territory a front."

NOTE.—Mr. J. B. S. Haldane, in his little book "Callinicus" (Kegan Paul, price 2/6) divides poisonous substances into four classes according to their effect on men:—

(1). Gases and vapours which are poisonous when breathed, but have no effect on the skin, such as chlorine and phosgene.

(2). Those which irritate the eyes but are only poisonous in very high concentrations.

(3). Poisonous smokes, mostly arsenic compounds; in small amounts they cause sneezing, in larger quantities they cause pain of an acute kind in the head and chest. They penetrate respirators.

(4). Blistering gases, which are poisonous when breathed and cause blisters on the skin. Only one such gas, dichlorethyl sulphide or mustard gas, was used during the war. It is called "yperite" by the French and Russians.

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NOTES ON THE DESIGN OF T BEAMS IN REINFORCED CONCRETE.

By CAPT. W. A. FITZG. KERRICH, D.S.O., M.C., R.E.

NOTE: All symbols used have the same meaning as in the Reinforced Concrete Manual issued by the S.M.E., and page references are to the Manual.

(1) T beams in reinforced concrete are of two kinds; those in which the neutral axis is inside the slab, and those in which the neutral axis is outside the slab.

The former class are designed by rectangular beam formulae, the latter by T beam formulae.

Calculations with T beam formulae are very much more laborious than calculations with rectangular beam formulae.

The object of these notes is to show that, even when the neutral axis falls outside the slab, rectangular beam formulae may be used so long as the " equal strength ratio " is not exceeded.

(2) Since a complete set of graphs are given in the S.M.E. Manual, which practically eliminate the use of all formulae for R.C. calculations, it may seem of little interest to investigate the matter.

It must be remembered, however, that these graphs are only made possible by assigning fixed values to certain factors in the problem, viz. :—

$m = 15$
t (safe working) = 16,000 lbs./in^2
c (safe working) = 600 lbs./in^2

These are the values assigned to them by the L.C.C. regulations, and are generally accepted in civil practice in this country.

The constant advance in the strength and reliability of the materials used in reinforced concrete may at any time invalidate one or other of them, and render useless the whole or portions of the graphs.

In support of the above contention the following may be cited.

1. *R.E. Journal*, September, 1924. Report on the International Cement Congress. It is here argued that certain aluminous cement concretes have a safe working stress of 1,300 to 1,400 lbs./in^2.

2. *Concrete and Constructional Engineering*, September, 1924. The Modulus of Elasticity in compression of Concrete. According to this article the value of the modulus is 5.46×10^6. This would give a value for m of approximately 5.5.

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(3) T beams in which the steel is the ruling factor, i.e., those in which the steel is stressed up to the maximum safe intensity under full load, but the concrete is not, are calculated from the following formulae (see pp. 51-53).

$$B = t\ A_t\ (d - y)$$

$$\text{where } y = \frac{d_s}{3}\left(\frac{3n - 2\ d_s}{2n - d_s}\right)$$

$$\text{where } n = \frac{2\ r\ m\ d^2 + d_s^2}{2\ (r\ m\ d + d_s)}$$

Whether the steel or the concrete is the ruling factor is easily determined from the formula on p. 54 for the equal strength ratio.

$$r' = .0375 - .052\ s_t.$$

For a rectangular beam of the same breadth and total depth the formulae are (see pp. 16-17).

$$B = t\ A_t\ (d - \frac{n}{3})$$

$$\text{where } n = m\ r\ d\left(\sqrt{1 + \frac{2}{m\ r}} - 1\right)$$

The problem usually met with in practice is, knowing the load to be carried, to find the dimensions of the beam, and the amount of reinforcement necessary for the purpose. This can only be done by trial and error if no graphs are available, and the process is laborious. If it is possible to use the rectangular beam formulae in the place of the T beam formulae, i.e., to calculate a T beam as if it were a rectangular beam of the same width and total depth, a lot of time and calculation will be saved.

As soon as the value of m has been decided on, a graph plotting $\frac{n}{d}$ against r is easily got out (Graph No. 1 in the Manual), and the rectangular beam formulae are then obviously very simple. A series of such curves would be necessary for the T beam formulae, since in calculating n an independent factor (d_s) is introduced.

In the Manual, two sets of graphs (3a and 3b) are all that are required for rectangular beams, whereas seven (9a — 9g) are necessary for T beams.

(4) By comparing the two formulae for the value of B it is obvious that the percentage of error involved in using rectangular for T beam formulae is

$$\frac{\frac{n}{3} - y}{d - y} \times 100$$ where n has its rectangular beam value.

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The values of n and y however, depend on so many variables that the expression is too complicated for mathematical analysis; and it has been found necessary to fall back on numerical examples.

In Table A (see next page) the smallest depth of slab used in practice d=3" has been taken. The percentage of error has then been worked out for varying effective depths of beam from 18" to 30" the latter being as deep as the beam is likely to be with a 3" slab.

Different amounts of reinforcements have also been calculated for.

The following deductions can be drawn from the table:

(*a*) That the error is *always on the safe side* since $\frac{n}{3}$ is always greater than y.

(*b*) That the error increases with the amount of steel used, up to the equal strength ratio, when the formulae are no longer applicable.

(*c*) That the error increases as the depth of the beam increases in comparison with the depth of the slab.

The maximum error in the table is 4.28% and it is hardly likely that a T beam will be found in practice in which the conditions are more unfavourable, since the equal strength ratio has been reached, and

$$s_1=\frac{d_s}{d}=0.10$$

(5) In view of the many assumptions and approximations made in reinforced concrete calculations (for example b_s is arrived at from purely empirical formulae, see p. 49) it would appear that such a small percentage as this might be neglected, and all the T beams in which the steel is the ruling factor be calculated as if they were rectangular.

Even if results arrived at by this method are not considered to be sufficiently accurate, the limits within which it will then be necessary to do trial and error calculations with the T beam formulae will be very small.

(6) T beams in which the concrete is the ruling factor must be calculated by T beam formulae.

They generally occur when headroom is limited, and are not often met with in practice. As will be obvious from the graphs in the Manual a large increase in the amount of steel used only gives a small increase in the strength of the beam, and they are not, therefore, usually economical.

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TABLE A. FOR A T-BEAM WITH A 3 INCH SLAB.

$$\%\ \text{error} = \frac{\frac{n}{3}\ \text{(for rectangular beam)} - y\ \text{(for T beam)}}{d - y} \times 100$$

r	d=18		s_1=.167		d=22.		s_1=.136		d=26.		s_1=.115		d=30.		s_1=.100	
	$\frac{r^1}{s_1}$ = $\frac{r}{s_1}$	n/3	y	Error %	$\frac{r^1}{s_1}$ = $\frac{r}{s_1}$	n/3	y	Error %	$\frac{r^1}{s_1}$ = $\frac{r}{s_1}$	n/3	y	Error %	$\frac{r^1}{s_1}$ = $\frac{r}{s_1}$	n/3	y	Error %
.001		N.A.	in slab		.0073	1.17	1.13	0.19	.0087	1.38	1.23	0.66	.01	1.59	1.30	1.01
.0015	.009	1.14	1.12	0.12	.011	1.39	1.24	0.72	.013	1.65	1.31	1.38	.015	1.90	1.36	1.89
.002	.012	1.30	1.20	0.60	.0147	1.58	1.30	1.35	.0173	1.87	1.35	2.11	.02	2.16	1.39	2.69
.0025	.015	1.43	1.25	1.07	.0183	1.75	1.33	2.03	.0217	2.07	1.38	2.64	.025	2.39	1.40	3.44
.003	.018	1.55	1.29	1.55	.022	1.89	1.35	2.61	.026	2.24	1.39	3.45	.03	2.58	1.41	4.07
.00323													.0323*	2.67	1.42	4.28
.0035	.021	1.65	1.31	2.04	.0262	2.02	1.37	3.15	.0303	2.38	1.40	4.02				
.00362									.0314*	2.42	1.40	4.14				
.004	.024	1.75	1.33	2.52	.0293*	2.13	1.38	3.63								
.00413						2.16	1.38	3.78								
.0045	.027	1.84	1.34	3.00												
.00481	.0289*	1.88	1.35	3.18												

* Equal strength ratio. $r^1 = .0375 - .052\ s_1$

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ARTHUR FFOLLIOTT GARRETT PRIZE ESSAY, 1924.

"MODERN SCHEME OF WATER SUPPLY FOR A LARGE CANTONMENT OR TOWN WITH A POPULATION OF ABOUT 20,000 INHABITANTS IN A TROPICAL OR SEMI-TROPICAL COUNTRY."

By "SIGMA" (MAJOR A. P. SAYER, D.S.O., R.E.).

SECTION I.—INTRODUCTION.

THAT oft quoted person "the man in the street," essentially a town dweller, does not usually concern himself with how he gets his water. All he knows is that it comes in pipes and that he can get what he wants by turning on a tap. Occasionally he finds there is something beyond his control affecting it; he is called on to pay a water rate bill, or he finds an excavation by men "doing something to the mains."

To his more isolated country cousin water supply is a matter of personal labour. He is concerned with the source of supply and the labour of getting water from it. A combination of these two view-points would provide the rudiments of a supply scheme. Between them they give the source, the means of getting water from it, and its distribution. The quality, however, is not questioned, and that is the most important consideration in a modern scheme.

It is axiomatic that a pure and ample water supply is one of the greatest factors in the prevention of disease. In preparing and working such a scheme the pathologist and the engineer must proceed hand in hand.

Town life involves an unnatural density of population and that of itself is apt to breed disease and help its spread. If the natural resources permitted each individual to obtain his own supply independently, the health of the community would be at the mercy of individual carelessness. Efficient control can only be exercised over a limited number of sources of supply, the points most accessible to contamination, and proper purification can only be assured when the whole supply is treated in bulk.

The necessity for medical control is obvious under any conditions, but it becomes insistent in a town with a mixed population in a tropical or semi-tropical climate. There, individual resistance to disease is usually lower and the conditions are more favourable to its spread.

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In designing a project for a modern water supply under these conditions the doctor must fix the standard of purity for drinking purposes and must advise on the quantity and degree of distribution.

The engineer has to provide the water, bring it to the required purity standard and deliver it to the consumers in the necessary quantities, all at a minimum cost.

Each case will depend on local conditions. No two places are exactly similar, and the term "tropical or semi-tropical" covers wide variations.

It is not possible, therefore, to define a system suitable for all such places. All that can be done here is to review the chief components of a modern scheme and the forms they may take.

From that, and from the study of existing systems in similar places, it should be possible to develop a suitable modern scheme for any particular place.

The following points of such a system will be dealt with :—

Source of supply.
Bulk supply.
Purification.
Distribution.
Control.

II.—THE SOURCE OF SUPPLY.

Water occurs in various forms, its natural cycle being from the the sea by evaporation to the air ; from the air by deposit as dew or by falling as rain, snow, etc. back to the sea or on to the ground surface ; thence, by flow along the surface or percolation through it, back to the sea. Occasionally a break from the cycle occurs when the surface flow or percolation collects the water in some position whence it has no natural outlet. Any of these stages may be utilised for obtaining a supply. The practicable sources for supplying a town are :—(*a*) The sea, (*b*) rain, (*c*) springs, streams, rivers, etc., (*d*) shallow wells, (*e*) deep wells.

The Sea.—As a source of supply, provides an unlimited quantity of water at small cost to coast towns, but the water is unfit for domestic or industrial use without treatment. The only satisfactory method of making it suitable for such use is by the costly process of distillation or condensation. The water thus obtained is somewhat dull and unpalatable, but is in its purest form. Owing to its high cost the supply of such water must be strictly limited. This source of supply, therefore, would only be adopted where no other could be used. Aden may be cited as an example of the use of this source of supply. There, the long periods without rainfall and the absence of wells and surface water give no alternative. In addition, in many sea ports condensation of sea water is used for marine and industrial purposes, and in some cases these plants

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form a reserve or stand-by for use in the event of failure of the normal source.

Apart from the requirements for domestic and industrial purposes coastal towns have in the sea a cheap and unlimited supply from which to draw for any purpose for which purity is not essential.

Such include fire protection, water borne sewage disposal, drain flushing, road watering and such like sanitary uses. This source of supply should, therefore, be investigated in a coastal town :

(1) For domestic and industrial purposes when no other source is possible.

(2) For protection and sanitary purposes in all cases.

Rainwater.—As a direct source of supply, is seldom used for a town. It is frequently made use of for individual purposes by collection from roofs of buildings, as the water is soft and usually free from impurities.. Such collection is, however, a source of danger in tropical and semi-tropical places on account of the encouragement to mosquito breeding. Individual collection and storage should be deprecated owing to the difficulty of control.

In many places, however, this source will repay consideration when dealing with a communal system.

The conditions that are necessary are :—

(1) A fairly steady annual rainfall.

(2) A convenient area for use as a catchment, that can be protected from fouling.

(3) Ample accommodation for suitable storage reservoirs.

If any of the following conditions are also present the cost of a supply system based on this source would be greatly reduced :—

(4) The rainfall is spread over a large part of the year.

(5) The catchment area is situated on a slope with an impervious surface or one that can be easily made one.

(6) The catchment area is at such a height that it can supply reservoirs situated at a sufficient height to eliminate or reduce pumping for distribution.

With regard to these conditions No. 4 reduces the storage capacity required. No. 5 reduces loss by percolation and evaporation ; it also permits of simple cleaning of the area by using the first rains to flush it and run to waste. No. 6 provides a gravity supply, the advantage of which is obvious.

It should be noted that the length of the maximum dry periods will fix the storage capacity required and the minimum annual rainfall will decide the area of the catchment. Gibraltar is an example of a place where the conditions are generally favourable. Originally individuals were dependent on their own collection, but now the supply under the control of the Sanitary Commissioners is gradually replacing this.

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The general system consists of a concreted catchment area high up on the sandy slope on the east side of the Rock. A channel at its foot collects and conveys the water to reservoirs cut inside the Rock itself at a level above the town. Thence it is distributed by gravity, except to certain raised or outlying points.

The cost of such a system depends chiefly on the cost of storage accommodation, and this will usually involve a separate distribution system for sanitary water.

Control of this source of supply is simple and upkeep small.

Streams, Rivers and Lakes.—This is perhaps the most common source of supply. Surface waters are usually soft, but contain many organic impurities, as the natural drainage of the country side is by the streams and rivers. Hill springs and streams are frequently drinkable without treatment. The method of using this source will depend on its form.

Springs should have their surroundings protected and fenced, and the actual outfall should be built up to prevent the water coming in contact with the ground surface. It should be piped to a collecting reservoir, whence it can be pumped as required. The output should be measured at the driest period of the year and calculations based on that minimum. Usually several springs will be required or they may be supplemented by other sources.

Hill Streams should be collected by catchment channels, which will allow excess or storm water to escape. Otherwise they should be treated in the same way as springs and their catchment areas acquired if possible, and villages, dwellings, etc., excluded.

Mussoorie, an Indian hill station, is an example of the use of springs and hill streams. No purification is required, but dispersed pumping and service storage are necessary owing to the number of sources and the grouping of consumers round the various hill tops.

Lake Water gives a simple source to operate and sometimes it is an advantage to form an artificial lake by damming a river or stream. The pump intake must be clear of local contamination so as to get the advantage of diffusion of impurities. The minimum inflow and the seasonal variation in water level in natural lakes must be noted. In artificially constructed or improved lakes weir outfalls steady this level. In such cases it is worth while considering the use of waste power of the outfall.

Naini Tal, another hill station in India, is an example of this. There, a high natural lake with a steep outfall provides the source of supply and the power for pumping as well as for electric lighting, by a hydro-electric plant.

River Water is usually collected from wells or sumps in its banks or bed. In tropical climates large variations in level must be allowed for and in flat country the possibility of changes of bed must be considered. Training works may be necessary, but when possible

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the pumping station should be situated where changes cannot occur.

As in lakes, points of local contamination must be avoided; the intake should be above a town if possible.

In special cases where no river or other source is available, it may be possible to lead water from a distant river by means of a canal, as is done at Ismailia and Suez, with the fresh water canal from the Nile. Canal water is, however, usually much more liable to contamination than river water.

For any of these sources the question of water rights must be considered and, if necessary, the cost of compensation must be included in the project.

Shallow Wells.—These are the traditional and almost universal sources of supply in the plains of India and other similar places. They are sunk in or near rivers or into water holding strata, that is, in the permeable subsoil immediately below the surface, and are in consequence very liable to contamination from sewage, manuring of fields, etc. They will be steined with masonry or brickwork to prevent caving in. It may be found advantageous to extend their collecting area by means of horizontal adits or galleries below water level. The yield of wells may be ascertained by pumping tests or more simply by recuperation tests. For each well there is a critical output; if this is exceeded the surrounding soil will be disturbed and the well will silt up or may cave in.

For each well there is a "cone of depression," and if the cones of two wells meet, the output of one will be affected by pumping from the other. The wells must, therefore, be dispersed.

This leads to pumping difficulties. Adits must be run below water level to a central sump—a difficult matter; syphons must be arranged—a likely source of trouble; or a suction pipe from a central suction chamber must be led to each well, involving loss of power. Otherwise separate pumps and dispersed power must be applied.

One well and pump per house or group is possible, but this defeats control, the main principle of a modern system. A shallow well source has, therefore, little to recommend it for a town supply.

Deep Wells are distinct from shallow or surface wells in that they pass through a stratum that the local surface water cannot penetrate and tap sources below it.

Owing to the wrinkling of the earth's crust, strata through which water can percolate freely may occur on the ground surface in one place and be carried at considerable depths in others. A stratum such as this, with an impervious layer beneath it to prevent further percolation, and another such layer above it to prevent access of surface water, is the source aimed at by a deep well.

In some places the lower impervious strata may form a cup

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which collects the subsoil water and retains it. Such water is under pressure, or, at least, if the upper retaining layer of impervious stratum is pierced by a tube, the water will rise in it, owing to the hydraulic gradient. The nearer the water reaches to the surface, the less pumping will be required and, therefore, the greater the efficiency of this source of supply.

Some places are fortunate enough to find such wells artesian in action, that is to say, the water rises to or above the ground surface.

The possibility of using such a source of supply depends entirely on the geological formation of the locality and its surroundings. If the geological formation and history is known, well and good. If no previous deep borings have been made the possibility of sinking a trial bore must be considered.

The usual form of these wells is an iron tube with the portion in the strata to be tapped in the form of a strainer, which allows the entry of water, but excludes the sand and gravel that carries it. Its diameter is kept as small as the pumping arrangements will permit, consistent with a good yield. It is sunk in the ground by sinking a boring pipe of larger diameter. This is forced vertically down by pressure while the earth, rock, etc., inside it is broken up and removed. The boring pipe is removed after the strainer and tube, suitably shrouded, have been lowered inside it.

Meerut Cantonment in the U.P. District, India, may be cited as an example of a case of the successful use of this source of supply. There a 10-in. tube well supplies all barracks and cantonments, and the yield has at times reached 35,000 gallons per hour: in this case the depth of the well is only 270 feet.

A similar scheme is being installed in Allahabad Cantonments to replace the doubtful municipal supply. There the tube depth is 300-ft., pumping depth 120-ft., with anticipated yield of 1½ to 2 cusecs per tube.

Points to be remembered in considering this source are :—

(*a*) The water is generally fit for drinking without treatment.
(*b*) The cost of sinking tubes increases considerably with the depth.
(*c*) Pumping costs vary inversely with the approach to artesian effect; and
(*d*) Above anything else the geological formation must be suitable.

SECTION III.—BULK SUPPLY.

Under this heading the chief requirements between the source of supply and the distribution system will be considered. Such arrangements for purification as may be necessary properly come under this head, but will be dealt with separately.

Pumping Plant.—In nearly every case pumping will be necessary at some stage while dealing with the water in bulk. The type of plant to be used will depend on the conditions of the particular

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case. This plant has to give long and regular service and the efficiency of the whole system depends on it. It must be realised that the standard of efficiency of the staff in a tropical or semi-tropical place will generally be considerably below that ruling in England; similarly, the standard of supervision may be lower. In any case the expert inspection and advice of the manufacturers will not be available and the time taken to obtain parts for replacements will be long.

For these reasons the plant selected should be of proved reliability and such that no particularly expert supervision is required nor frequent fine adjustment necessary. Sub-divisions or "sets" should be standardised so that spares will serve any "set" and delays of special manufacture will be avoided. Provision must be made for reserve or stand-by plant to prevent interruption of the service and to meet emergencies.

Types of Pumps.—The type most commonly used is the double acting lift and force pump; it is simple in action and simple to maintain.

In some cases centrifugal pumps are more suitable, on account of their compactness and high lift capacity. They require rather more attention and more expert adjustment than the former type. Another form of pump that has developed from the centrifugal pump is the vertical-spindle tube well pump. It consists of a series of vanes or impellers on a shaft working centrally in a tube, either the tube of the well itself or a special tube lowered into the well. Each impeller raises a column of water to the next above. Such a pump needs very careful adjustment and very specially designed bearings.

Another type is the air-lift pump suitable for tube wells, but uneconomical except where one compressor can serve several tubes.

Power Plant.—Steam plant, internal combustion engines, electric motors, or water power may be used; wind power can be used for individual wells, but is too variable for normal use for water supply. The choice is not decided solely by the cost on site of the fuel nor on the cost per H.P. produced. Each type has its particular advantages which must be considered in connection with the particular conditions.

Steam plant is very generally used. It is usually economical for the steam producing plant to be used continuously, and it is, therefore, suitable when one boiler house can supply pumps that can be used alternately.

Internal combustion engines driving pumps direct are suitable for periodical pumping when the pumping points are separated.

Electric motors are convenient for dispersed pumping as the power can be easily distributed though centrally produced and controlled.

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Water power for direct pumping may be used occasionally but it is usually better to instal a hydro-electric plant and pump electrically.

Reservoirs.—Some form of storage is required to deal with the water in bulk. Normally open reservoirs for untreated water and a protected "clear water well," with the purification arrangement between, will be provided. The rate of supply will decide the capacity of the former and the rate of consumption that of the latter.

When possible, reservoirs should be excavated, to reduce the thickness of walls required, and floors and walls should be impervious, to avoid percolation losses. They should be large in area rather than deep; an increase in depth means a large increase in capacity, but a loss of head. They should be divided to permit periodical cleaning. In cases where the supply rate falls below the consumption rate during parts of the year, special storage arrangements are necessary. These will usually take the form of impounding reservoirs, and their capacity is fixed by the maximum deficiency for the maximum period, due allowance being made for evaporation and other losses.

SECTION IV.—PURIFICATION.

No natural source produces absolutely pure water: the solids, liquids and gases with which the water has come in contact contaminate it.

The impurities are carried in three forms: suspended, colloidal and dissolved, and may be organic or inorganic. For drinking purposes organic impurities are the chief concern, as these carry harmful bacteria. The salts in solution are usually so diffused as to be harmless, but analysis and medical advice will show if special treatment is necessary. For domestic purposes other than drinking the degree of hardness is of importance, as it is also for boiler feed-water, etc., and industrial use.

The methods of freeing water from impurities can be roughly divided into storage, filtration, chemical treatment and heat treatment. Any of these, or a combination of them, may be used, but the last is impracticable for town supplies.

Storage.—This allows sedimentation, by which suspended matter is deposited, equalization, by which abnormal pollution is diffused, and the time taken to pass through the reservoirs kills the bacteria. It involves rest or slow movement for the water and, therefore, requires large reservoirs.

Filtration.—Mechanically removes the impurities by passing the water through a material that will prohibit the passage of the impurities.

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This may be effected by slow flow through graded sand filters, in the upper layers of which a film forms that holds up the finest particles and the majority of bacteria. Rapid or pressure filters are less satisfactory for domestic supply. As a possible development the Hele Shew pressure filter with sheets of water-proof paper under pressure, might be examined as it promises minute filtration in small space.

Chemical Treatment.—May be employed for three purposes: (*a*) to kill bacteria, (*b*) to coagulate suspended matter and in precipitating it to carry with it the bacteria and finest colloidal impurities, and (*c*) to soften the water.

For the first purpose the most generally successful treatment is chlorination.

Some form of mechanical device should be employed, such as a "Chloronome," to treat the water as it flows and to regulate the dose. If too much is added the water tastes and has to be treated with sulphurous acid or other means. For the second, sulphate of alumina is added to the water, and reacting with the carbonates in the water forms the insoluble hydrate of alumina, which is precipitated. This precipitation or coagulation is of assistance in forming the film in the sand filters.

It should be noted that electrical coagulation is a possibility, but at present it is still in the theoretical stage.

For softening, two forms of treatment may be necessary, one for the temporary and one for the permanent hardness. Usually for domestic use treatment of the temporary hardness will be sufficient. The treatment consists of absorbing the carbonic acid held by soluble bicarbonates, thereby producing insoluble carbonates. This can be done by heat or by the addition of slaked lime.

Permanent hardness is chiefly caused by soluble sulphates, which, by treatment with sodium carbonate, are converted into insoluble carbonates.

Each of these processes can be mechanically applied, and some means of automatically regulating the quantities should be used.

The purification necessary will be decided by the result of analysis of the water from the source, and this must be continually watched for variations. The costs must be considered with the scheme as a whole, and sometimes it may be found better to choose the less pure of two sources if the ultimate cost is lower.

Section V.—Distribution.

The distribution system may take many forms. In its simplest form, which may be called the "village pump" system, each individual obtains his supply from a fixed point and provides his own transport. In the most elaborate form the water is carried to each house by pipes, from which an unlimited supply can be

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obtained at any time. It may even take the form of a double system, one for domestic water and the other for sanitary and other purposes.

The actual form that a modern system will take for any particular place will depend on several conditions. Firstly, on the standard of living of the consumers; secondly, on the local conditions, topographical and climatic; thirdly, on the capacity of the source of supply and the cost of production.

The chief object to be attained in a modern supply system is a pure and ample domestic supply. Purification has already been dealt with and the second condition can only be complied with fully by providing a continuous supply.

Pressure and Gravity Distribution.—The actual daily consumption will vary with the different seasons of the year and will not be evenly spread over the twenty-four hours. Were the supply taken direct from the pumping station the plant would be over-taxed at some hours and under-worked or partly idle at others. This is uneconomical and raises the running costs. Direct pumping into the distribution system is practicable when periodic supply is given or to supplement a small capacity continuous service at the heavy duty hours.

Whenever possible pumping hours should be limited by the provision of a service reservoir, which can be filled by pumping in a few hours.

Service Reservoir.—From the service reservoir the distribution system will be served continuously by gravity. It should be noted that a gravity supply will probably involve additional outlay, but will give lower running cost. In order to serve all parts of the town the service reservoir must be raised to such a height, either naturally or artificially, as will provide sufficient head to force the water to the furthest or highest point of delivery.

In selecting its site a balance must be arrived at between the following factors; (*a*) length and cost of rising main; (*b*) saving in cost of construction by using a naturally raised site; (*c*) a reduction in cost of the distribution system by siting near the "centre of consumption"; (*d*) other local factors that may affect the site, such as security and accessibility.

The capacity of the service reservoir must be sufficient to ensure a continuous supply during times of maximum consumption. It is advisable, therefore, to allow for at least double the normal requirements. To avoid interruption the reservoir should be divided into compartments, which can be cut off periodically for cleaning

Finally the service reservoir must maintain the purity standard of the water and give no opportunity for contamination, and on this account it must be covered.

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Piped Distribution.—As the water to be distributed is under pressure, steel or iron pipes are required to carry it. They also prevent contamination from outside.

They should usually be buried in the ground or otherwise suitably protected.

The pipes will vary in size according to the maximum volume of water they are required to carry. It is more economical to run one large pipe than two smaller ones to carry the same quantity of water. In consequence the distribution system will normally consist of a few radiating mains of large diameter, gradually reducing in size as their duty decreases, with sub-mains, loops and branches of smaller size carrying off supplies at intervals to the delivery points.

The mains should run direct to, and through, the largest centres of consumption. It is advantageous, but not essential, to arrange loop-mains or sub-mains, as they assist the supply to distant branches and enable sections to be isolated for repair without interruption of the service.

Each part of each main and branch must be designed for the maximum duty it has to perform. The governing factors are (*a*) a minimum residual head, (*b*) a minimum supply in gallons per minute, (*c*) a maximum rate of flow in the pipes, (*d*) a capacity of double the normal consumption or a capacity to give the daily supply in a period of from four to twelve hours.

Degree of Distribution.—The more highly educated the classes of a community are, the greater will be their demands on the water supply system, both as to quantity and convenience. As the standard of living increases, the adjective "necessary" grows in its application and gradually covers what was previously classed as desirable or even luxurious. It is obvious, therefore, that the same degree of distribution over the whole supply area is unnecessary. This is particularly so in a tropical or semi-tropical town, where, it may be assumed, there is a mixed European and Native population.

In the Cantonment or small town under discussion, it will usually be found that the classes into which the inhabitants are divided also define the areas occupied. This makes it simple to provide the suitable degree of distribution to each area.

A general class division may be made as follows :—

(*a*) Military, British and Native.

(*b*) European Civilians; Military Officers should be similarly treated.

(*c*) Natives, divided into upper and lower classes, and perhaps also by religion and caste.

(*a*) *Military—British.*—Owing to the definite routine ordering the life of this class, definite hours of supply can be fixed, making a continuous supply unnecessary. Delivery points are few and

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are laid down by military regulations. Connections should also be given to married quarters as for corresponding civil grades.

Native.—A still simpler scale of distribution is required, little more than supply to cook houses and bathing places is necessary. For Native Officers' quarters and married families and followers, it is usual to provide standposts from which occupants can draw their supply. In both cases water points will be required for sanitary purposes and will usually be provided in the form of standposts. These can also serve for watering, drain flushing, etc., as required.

(*b*) *European Civilians.*—For this class the highest grade of distribution should be provided. Each house should have a separate connection providing a continuous service.

The internal distribution is a matter for the individual house holder. It should, however, be noted that it is an advantage if such houses are provided with house-service tanks with automatic arrangements for refilling as water is drawn off.

Such tanks must, of course, be properly protected against contamination and mosquito breeding. The advantage gained is in the reduced capacity of the service pipes required; where taps are served direct the capacity should be sufficient to give the whole daily supply in from four to six hours, whereas with the small reserve of the house-service tank eight or twelve hours may be allowed.

Apart from the actual house connection, additional connections to garage, stabling, laundry and servants' quarters will be required, and if water is plentiful a garden connection may also be given. These can take the form of standposts.

For the lower class Europeans a connection should be given to each house, but a house-service tank is usually inadvisable.

Bathrooms and cookhouses should receive a direct supply and usually one standpost for servants' quarters, etc., should suffice.

(*c*) *Natives.*—The upper class natives should be graded for distribution approximately as the lower class of European, though in many cases one delivery point in the house will be found sufficient.

For the lower or menial classes usually congregated in bazaar areas no house connections should be given. A series of standposts should be supplied so that each house is within 100 yards of a supply point.

Sanitary Service. Apart from the domestic supply the distribution system must provide for sanitary requirements, which are communal responsibilities.

They require ample supplies and proper care. Most of them do not require the same standard of purity as for domestic supply, and if the cost of production of the pure water is high the possibility of a separate supply and distribution should be considered.

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A double system is costly and should only be adopted when the saving in running cost justifies the increased outlay. When a double system is used particular care must be taken to ensure that the "sanitary" water is not used for domestic consumption. It is a help if such water is sufficiently brackish to be unpleasant to drink.

Sewage Disposal.—No mention has been made so far of this important sanitary question. In the majority of small towns and cantonments in the tropics there is no water-borne system or, at any rate, it has not been developed to the stage of serving each house. If such a system exists provision must be made for a larger allowance of water and, to be possible in a hot dry climate, at least double the quantity required at home must be provided. In preparing the water supply scheme the possibility of the introduction of the system must be enquired into if it does not already exist.

Fire Protection.—A modern water supply system must include provision for fire protection. Hydrants should be provided on the mains, capable of providing a minimum supply of 120 gallons per minute. Important buildings should be served by at least two hydrants each capable of giving this supply at the same time. These hydrants can frequently be combined with service points for sanitary purposes. Generally speaking, the flow required at a hydrant will decide the size of the main, but the pressure will be determined by the normal supply.

Industrial Supply.—A supply will be required for pumping and power stations, and such industrial concerns as are included in the area. If any special form of purification is required it should generally be provided by the consumer. If an extensive industrial supply is required, it will probably be more economical to keep it distinct from the domestic supply.

Finally, it should be noted that increased cost to consumer is not a really effective waste preventer. If, therefore, the supply is costly definite means should be taken to limit the consumption. This can be done by (*a*) limiting the rate of flow in the house connection; (*b*) limiting the hours of supply.

A more drastic means is to refuse house connections, thereby necessitating daily deliveries by water cart or other means of transport. Aden and Gibraltar have been cited as examples where drinking water is limited and costly; such limited distribution is used in both cases.

Section VI.—Control.

In a Military Cantonment the construction and control of the water supply rests with the military authorities. Funds will be provided in the military budget and provision will be made for

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the executive staff. Definite regulations cover such a supply and provide for extensions to non-military consumers.

In the case of a town or cantonment where the military interest is small, the control rests with the local civil authorities, usually an elected or partly elected Board. Such a Board will usually license a Company to provide and maintain the water supply, but it may raise a loan to meet the initial outlay and construct and maintain it as a municipal concern.

In either case, the Board must retain responsibility for fixing the requirements and the purity standard and for medical supervision.

Quantity Required.—This will be determined by the doctor and engineer in consultation with representatives of consumers and such industrial and agricultural interests as may be concerned. The effect of local conditions, including the method of sewage disposal, must be carefully considered and full allowance made for extension.

Normally the total daily consumption for all purposes should not exceed 25 to 30 gallons per head. In detail Europeans should be calculated at 15 to 20, Natives at 5 to 8 and animals at 10 gallons per day. Large houses connected should be allowed from 300 to 500 and small from 200 to 300 gallons. Special allowances should be fixed for sanitary purposes, such as road watering, drain flushing, etc., and for special consumers, such as power plants, farms, laundries, refrigerators, ice and mineral water factories, etc.

Cost of Water.—This will be determined by dividing the annual cost by the quantity used. The annual cost must include fair interest on the capital outlay, possibly provision for repayment of the debt, percentage charges for depreciation and renewal of the various parts of the system, annual running costs of plant, including the pay of the staff employed, maintenance and repairs, both labour and materials, office expenses and the cost of collection of charges, including an allowance for late payments.

Generally speaking, the cost should be calculated so as to make the system self-supporting, but not a profit-earning concern.

Recovery of Cost.—A provision is made in the military budget to cover the cost of water consumed by troops. Certain ranks are not entitled to a free supply of water and the cost is recoverable from the individuals. For those occupying Government quarters, which are more or less of standard sizes, it is simple to fix a flat rate charge according to the quarter occupied. The recovery of this is simple, as it can be charged with the rent.

In the case of other consumers the local authority should determine the method of payment and should be responsible for the recoveries.

In a small town house connections should be metered and the actual consumption should be billed for. Meters involve a certain

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amount of additional expenditure, and extra staff is required, but they give the only fair means of fixing payment for quantity.

Other methods, such as a water tax on the rateable value of the house, or a " ferrule " rate determined by the size of pipe supplying the house, make no distinction between the careful and the wasteful occupier.

Whatever method is adopted the local authority must make provision to cover the cost of water for general purposes, and that used by the non-taxable portion of the community in addition to the supplies to individuals.

Waste Prevention.—This can only be achieved by constant inspection and immediate repair or replacement of leaks or damaged fittings. All mains and sub-mains should have valves at intervals and every branch should be capable of being cut off by a stop cock. District or area meters are an aid to the detection of undue consumption in any particular part of the system.

Section VII.—Conclusion.

The foregoing remarks have touched upon some of the main features of a water supply system under certain conditions. They do not define a system in detail nor do they attempt to teach the method by which a project for such a system should be worked out. They are offered simply as a guide to the inexperienced and a reminder of the various matters that require consideration.

If submitted to " the man in the street " or his country cousin, they would probably leave him as ignorant as he was before. However, such people are seldom entrusted with the preparation of a scheme for a modern water supply.

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WATER SUPPLY, GIBRALTAR.

By MAJOR H. E. COAD, A.M.INST.C.E., S.R.E.S.

GIBRALTAR possesses no rivers or springs and the population, which numbers about 17,500 civilians and 3,600 naval and military members, depends almost entirely for its potable water supply on rainwater caught on artificial catchments. This supply is supplemented to a very small extent by water from shallow wells and from distillation plants.

Every dwelling-house must by law have its own underground masonry tank. Water is led direct from the roofs to these tanks and is accordingly more or less polluted by droppings of birds and cats and by the dust blown up from the surrounding areas and deposited on the roofs. Many of the roofs are flat and are used for recreation in the evenings and for drying clothes in the daytime and are further contaminated accordingly. Frequently *bacillus coli* is found in 10 cubic centimeters of drinking water or less, but little trouble is caused on this account, the inhabitants, through long use of such water, being immune. The following extract from the Annual Report of the Medical Officer of Health, Gibraltar, for 1907, is of interest in this connection :—

> " The drinking water which is mainly derived from rain water collected on roofs and specially prepared areas, is inevitably open to contamination. The result of bacteriological examinations shews that B. Coli, the typical organism of sewage contamination, can be isolated in 10 c.c. of practically every sample of water collected on the Rock, and many specimens contain it in even 1 c.c. It is doubtful in how far one can apply, to a water collected as that in Gibraltar is, the same bacteriological standard which we apply in the case of well or spring water, and this appears to be the view held locally. The typical B. Coli having been found in 10 c.c. of most waters collected from roofs, which have been consumed for years without apparent detriment to health, it has been the custom to pass such waters as " fit " for drinking purposes. Water containing B. Coli in 0.1 c.c. has been condemned, as an inspection of the source of supply has usually shewn distinct evidence of contamination by sewage in these cases. An open mind has been kept as to the presence of B. Coli in 1 c.c. of water, the opinion

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formed being commonly based on the combined results of the chemical and bacteriological examinations, and on the results of the inspection of the source of supply. Under ordinary circumstances, as in the case of a water supply from a well or spring, the presence of B. Coli in 10 c.c. of water would be considered a sign of definite and serious contamination. The Sanitary Officer comes to the conclusion that " it is evident that, in spite of all precautions, contaminated dust gains access to most of the tanks, and this is not surprising when one considers the physical conditions which obtain in Gibraltar."

Rainwater is not collected from garrison roofs at the end of the dry season until the roofs have been well washed by the autumnal rains, bye passes being provided in the collecting pipes for this end.

The rainfall averages 33 inches per annum and this is spread over eight months, June, July, August and September being generally entirely dry months.

The collection from house roofs is supplemented by large supply and reserve tanks fed from special catchment areas. These are generally remote from crowded districts and are consequently freer from dangers of contamination than the ordinary house roofs. The catchments are of three kinds—(*a*) ordinary rock surfaces stripped of earth and vegetable growths, with cracks and crevices stopped with concrete and cement mortar. About 30 acres of these are used. (*b*) Prepared areas of thin concrete. (*c*) Areas covered with corrugated galvanized steel, supported on small creosoted piles and runners. The latter areas, which cover in all about 35 acres, are situated on the sandy slope on the East side.

Generally these catchments are well fenced to keep out sheep and goats and are provided with silt pits at their lowest points, and also, in the case of the smaller ones, with mosquito-proof gauzes at the entrances to the tanks.

It has been found advisable to cement wash the catchments annually, those of corrugated steel included, both for the sake of cleanliness and for diminution of losses by leakages and evaporation. The latter are very heavy after intermittent showers.

Special provision of adequate spill ways in the channels at the foo of the large catchments has had to be made, since the danger of stoppage of the channels by blown sand, and at times by hail, is great. From such large areas, catches of a million gallons per hour are common, and a stoppage in the collecting channel once resulted in the retaining wall at the foot of one of the catchment areas being swept away.

The reserve tanks vary in capacity from 80,000 gallons to 1,000,000 gallons. These are generally constructed below ground for protection from gunfire. In the case of the supply tanks for the civilian population five tanks, with an aggregate capacity of 7,000,000

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gallons, have been made in the heart of the mountain and are absolutely bomb-proof.

No filtration of any sort is practised in Gibraltar, but a period of 15 days is allowed for settlement in the main civilian tanks before the water is used. The average annual collection over the Council catchments is 20,000,000 gallons, of which about 15,000,000 gallons are utilised for domestic purposes, the remainder being diverted into the sanitary water reservoirs. The potable water is piped to points in the town, where it is sold to the inhabitants, who obtain it in buckets and tins, at a cost of 2s. 4d. per 100 gallons. Few of the houses have a direct metered fresh water supply. In years of drought—for example, in 1922, when the rainfall was only 25.8 inches—drinking water is shipped in barges from Algeciras and delivered to the inhabitants. The Military resources are, however, always adequate without such assistance.

The practicability of obtaining a constant supply of potable water from the neighbouring Spanish mountains has been investigated, but owing to the peculiar character of Gibraltar as a fortress, such schemes have up to now been rejected.

A supply of brackish water termed " sanitary water " is installed in every house for use in W.C.s, baths and sinks. Its source is the flat sandy neutral territory, where it overlies the sea water at a depth of about 6 feet. It is obtained by pumping from a large number of shallow wells, from which it is lifted by relays to the top of the Rock. About 240,000,000 gallons are pumped annually. Up to the end of the wet season it approximates in quality to fresh water and becomes more saline as the upper layer of water is used up. It is sold at about 3½d. per 100 gallons.

A third source of supply is from wells on the North Front, which yield about 6,000,000 gallons per annum. This water is sold to the shipping for filling boilers, at 9d. per 100 gallons. It is not potable.

There are many small private wells at various points in the fortress, none of which now yields pure water. They are, however, used by the inhabitants to a small extent.

On the whole, the water supply in Gibraltar is good, the only improvements now contemplated being the extension of the main civil supply tanks and catchments, and a large extension of the direct supply of potable water to the houses.

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THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914-19.

EXPERIMENTAL SECTION (*continued*).

CHAPTER 6.— MESSAGE CARRIERS.

Experiments were not carried out to any great extent by the Experimental Section with Message Carriers till the Spring of 1917.

The first suggestion for keeping communication during a battle was to throw a cable and thus connect up by telephone.

During 1915, the Rocket was suggested for this purpose. Experiments had shown, however, as in the case of apparatus for destroying wire entanglements, that the rocket was an unreliable instrument. Its range and direction were both uncertain, but for communicating messages something reasonably accurate was essential. The "Boxer" rocket threw a line about 400 yards, and the "Schumuly" rocket apparatus could only be relied upon for 250 yards. The latter was also too heavy to carry over open ground, and at 250 yards communication could be maintained by visual signalling.

A series of experiments during the Spring of 1915 showed that the Pain, Schumuly, and Boxer Rockets were all unsuitable for the purpose.

Attention was turned to fitting written messages into projectiles that could be fired from the rifle or the smaller mortars. The Second Army pattern of Message Carrier, fired from the Stokes Mortar, was a cast iron projectile containing flare composition which gave a trail in flight and on the ground; but it invariably buried itself in the ground and could not easily be dug out, and remained too hot to handle for some considerable time. Many inventions on similar lines were submitted to G.H.Q., but only on two patterns were experiments carried out. One type was made in the shape of an arrow, with a hollow stem mounted on a stick fitted on the end of the rifle and fired by a blank round. It was not satisfactory and the range was poor. The other pattern, with its flare and message, was projected from a cup with a rod attached. When fired from the rifle, the projectile left the cup attachment and started the flare burning. Its flight, however, was very erratic and it was unsatisfactory.

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In 1917 a pattern was designed in the Fourth Army. This was also on the rocket principle, and was given up owing to its erratic flight.

The chief objects which had to be borne in mind in devising a Message Carrier were :—

(i) That it should be visible in its flight to indicate its arrival and direction to the receiver, and if possible carry a whistle for this purpose.

(ii) That it should be invisible at the beginning of its flight so as not to give away the position of the firer.

(iii) That it should not bury itself too deeply nor remain too hot to handle for taking out the message.

(iv) That it should be fairly accurate, and obtain a range of at least 600 yards.

In the summer of 1917 the M.I.D., sent out a Message Carrying Rocket (the Wynne pattern), which had been experimented with in England and which gave fairly good results. The projectile was about 4 feet long and was propelled on the principle of the rocket, but had vanes at the back on which the gases impinged, causing it to rotate and thereby giving it a much steadier flight. Contrary to usual practice it carried the rocket composition in the head, so that the vanes were carried on the tail. The tail contained light smoke composition, giving a light trail in the air and smoke on the ground, and the nose carried a syren operated by the inrush of air. This projectile marked a great advance in the history of rockets. It obtained a range of 2,500 yards and was accurate to within 200-300 yards. The message was carried in a tin cylinder in the top of the tail, which unscrewed from the head. This rocket was introduced into the service in the early part of 1918 and was much in demand.

At the same time as the Wynne Message Carrier came out, the Geake apparatus for throwing a wire, and also the Geake Message Carrier were demonstrated. The message carrier consisted of a hollow tube with its message and composition in the head. The tube fitted over a spigot about two feet long, in the head of which was a striker. The principle was the same as that used in the Foulis Stick Gun and in the "Granatenwerfer" used by the Germans for bomb throwing, and was the reverse of a gun. Instead of the projectile fitting inside the bore of a barrel, the projectile carried a barrel or tube fitting outside a solid spindle. The charge was carried in the head of the tube, and the striker in the spindle fired it when actuated by a trigger mechanism in the base of the gun. The Geake message carrier travelled about 1,000 yards, but the rocket pattern was the one preferred, as no gun was necessary for firing it, and the range was greater.

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The Geake cable thrower, which threw a special telephone wire 350 yards, was on the same principle, but was a much stouter and heavier weapon. It was eventually reproduced almost exactly in the German cable thrower, which was of still stouter construction.

The objection to all cable throwing devices was that the wire was liable to be cut by bursting shell, and nothing could be done to prevent this. An independent message-carrying projectile without a cable was therefore preferred, and at the time the Wynne pattern met the demand.

The Experimental Section carried out experiments in design of a Message Carrier to be fired from the discharger which had been introduced for the Mills Grenade. A French pattern (Plate XIV, Fig. 1) fired from the discharger, was in the form of the ordinary grenade, only without a hole, so that it was fired with a blank round instead of a bulleted round. Its range was only 200 yards, and the projectile in soft ground could not easily be found; also the smoke emitted was not good, neither was there any indication, except for the smoke trail, of its arrival.

Experiments were continued in England on similar lines to those carried out in France in the winter of 1917, and a fairly hopeful design was arrived at, similar to that illustrated in Plate XIV. Fig. 2. It consisted of a thin tube containing a flare composition and smoke composition with a whistle at the head and three vanes on the back. The end carrying the vanes sat in the discharger, and was propelled by a disc with two clips fitting loosely between the vanes, the disc falling off directly after firing, as soon as it left the rifle, the composition being lit on shock of discharge by a cap fitted in the base end of the tube.

This device, with which considerable experiment was carried out both in France and in England, did not mature until March, 1919, as considerable difficulty arose in manufacture, which could not be got over. A series of trials of the manufacturers' samples were attended by the O.C. Experimental Section during the whole of 1918. Though the weapon could be made in the Experimental Workshops, difficulties arose in bulk supply with the composition owing to the small diameter of the tube. At a final trial in March, 1919, it was decided to use a heavier weapon with a $\frac{5}{8}$ inch tube instead of $\frac{3}{8}$ inch, and to do away with the whistle. The projectile was recommended for introduction into the service with these alterations, the whistle being replaced by a head which splayed out on entering the ground, so that the projectile would sit in the ground and be fairly visible while emitting smoke (sparks for night use) for about $1\frac{1}{2}$-2 minutes. A bright flare was emitted in flight, sufficient to catch the attention of the sentry posted to observe it. This final pattern of projectile is that illustrated on Plate XIV, Fig. 2.

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CHAPTER 7.—TRENCH MORTARS.

The first trench mortars that were made in the earliest days of trench warfare were 4 inch and 3.75 inch (or 95 m.m.) diameter bore. Both of these were of local manufacture and were necessarily make-shifts.

The 4 inch had a range of 325-550 yards, firing a 7-lb. shell with a percussion fuze, which was dropped into the mortar and fired by a friction tube. The 3.75 inch had a range of 50-200 yards, firing a jam pot bomb weighing about 2-lbs. with a time fuze lit by explosion of the flash powder propelling the charge. The 95 m.m. mortar is illustrated on Plate XV, Fig. 2.

The Experimental Section was called upon to supplement the supply of ammunition by making up bombs from local materials.

The details given on Plate XV, Fig. 1, show the crudeness of the projectiles. These were made up in the backyard of a farm near St. Omer, and were turned out in large quantities.

In January, 1915, the use of some form of smokeless powder became vitally necessary, in order to conceal the positions of the batteries as far as possible; and the home authorities took up the question of production of mortars with suitable ammunition.

For a time guncotton was used as a propelling charge, which necessitated increased contents of the chamber space below the projectile and reduced range.

March, 1915, saw the first mortars sent out from England, the 1.5 Vickers with 18- and 33-lb. bombs, and the 2 inch Woolwich mortar firing the 50-lb. "football" bomb.

During this period experiments were carried out by the Experimental Section to develop an invention brought out to France by Col. Lewis of the American Army and Lieut. Breeze of the Royal Horse Guards. The invention consisted of firing from a mortar a shell on the principle of the rocket, and considerable experiments were carried out, the mortar and shells being manufactured locally, except for certain parts which had to be obtained from London and Paris. These trials continued for some considerable time and were successful on the whole; but, owing to the great visibility of the trail of the rocket and consequent danger of the battery position being easily located, together with the erratic flight of the projectile, the Rocket Gun was dropped and superseded by the 2 inch Trench Mortar produced at Woolwich.

During these experiments, Lieut. Breeze lost his life owing to a premature burst of one of the rocket shells just as it left the mortar.

Experiments continued for some time more, and, when the rocket principle was dropped, the apparatus was converted into a mortar and experiments were continued on these lines.

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The rocket gun itself gave a range of 1,200 yards, and the shell weighed about 36-lbs. with the rocket, and contained 10 lbs. of high explosive; but the rocket had always a tendency to fly with its nose into the wind; and it was never safe to predict, when firing with the wind, the direction in which the shell would go, either away from or back again towards the firer.

The Mortar developed from the rocket gun had a range of about 300 yards, and the same shell was used. The body of the shell was of sheet iron instead of cast iron, so that fragmentation at the best of times was poor, and could not be compared in effect with the 30-lb. "football" bomb, with its ¾ inch cast iron shell forming a sphere about 10 inches in diameter.

In February, 1915, the first Brock Mortar was seen and tested in France, and contained many interesting features. These mortars were of light wire-wound steel pipe construction, and were of varying sizes from 3 inches to 12 inches in diameter. They were set in holes in the ground. The projectile carried its propelling charge on it, which was lit by friction ignition when placed in the mortar, the bomb being propelled after a short interval.

In nearly all cases black powder was used for lack of other explosives.

The advent of the Stokes Mortar in the spring of 1916, and the taking over of mortar production by the Ministry of Munitions put an end to the necessity for further experimental work, with the exception of local trials of fittings and minor details.

The Second Army Workshops developed the 6 inch and 9.45 inch Newton Mortars on principles similar to those of the Stokes, but with a different mounting. The mortar was carried on a heavy wooden base plate well braced, and its barrel directed to the line of fire by three adjustable ties, which held the mortar down on the base plate. The shells were vaned, and the charges placed in bags, between the vanes, in wire cages.

The Stokes, Newton and the 2 inch Woolwich Mortars held the field for the remainder of the war, though their spheres of usefulness became gradually restricted by the changing conditions of warfare.

In the spring of 1918 the Experimental Section was called upon to devise a light mounting for the 3 inch Stokes in anti-tank work, to be divisible into single man loads.

At this stage in the War a portable weapon was required for dealing at close range with possible enemy tanks, and the 3 inch Stokes Mortar was obviously the weapon for the purpose. This mortar was a most portable and highly efficient weapon, throwing an 11-lb. shell to a distance of 850 yards.

Several Divisions had evolved a method of firing the gun when slung over a man's shoulder, the gun being held by two wooden handles clamped to the barrel. In this way the Stokes had followed

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up Infantry advances, so providing means to engage the enemy rapidly with a heavy shell of great moral effect.

Experiments had been carried out at the G.H.Q. Stokes Mortar School in low angle fire, a wooden stick being used as a ramrod to draw the shell down the barrel, and operated by strings which broke off when the shell reached the base of the mortar and fired. This was only a makeshift, and in ordinary soil the base plate could not prevent the mortar from recoiling considerably at every round, so that the backing of the earth became loosened and would not stand up for continuous fire ; and this method was only reliable in fixed and prepared emplacements. A suitable mounting was produced by the Experimental Section in October, 1918, but owing to the Armistice in November, no further action was taken with it in France, the samples with description and drawings being sent to the War Office for further development after the War. This mounting is shown in Plate XVI, and also in Photographs (i), (ii) and (iii). The Bipod was detachable from the main frame, but, when mounted, the whole recoiled together, and carried a spade attachable at different angles according as to whether the mortar was firing at high or low angles. The mounting had a special trigger mechanism attached, and could be fired at angles from 7°-70° with a total traverse of 30°-40°. No part weighed more than 50 lbs. and the whole equipment was mounted on a light carriage, and could be carried as single man loads or on a pack saddle.

The 3 inch Stokes was also developed for anti-aircraft fire and the Experimental Section made all the fittings used as samples for manufacture in England. A separate base plate was made for all-round fire down to angles of elevation of 45°, and a pair of handles on a light iron frame with folding legs was used for operating the mortar, the mirror sight being carried on the same bracket. A pendulum clinometer was developed for this purpose, and various other mirror fittings were evolved.

CHAPTER 8.—CATAPULTS AND GRENADE THROWERS.

The first catapults were taken over to France in February, 1915, and tested by the First and Second Armies. The catapult was made by Messrs. Gamage & Co., to a design prepared at the S.M.E. Chatham, and gave fairly good results. It weighed 43-lbs. and consisted of a tripod carrying a canvas bucket with elastic slings. The trigger was not satisfactory and the whole apparatus was cumbersome and unwieldy to set up and use, and the ranges varied considerably. Still the demand at this time was considerable, and 100 were ordered for trial, and eventually in May, 1915, an establishment of 20 per Division was proposed. Only time bombs were used with this catapult as it was not considered safe to use bombs with percussion fuzes. The range obtained with the double cylinder

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hand grenade was about 110 yards, and was fairly accurate if the catapult was fixed securely. Longer ranges could be obtained up to 200 yards, with the2-lb. bomb, but not with accurate results. A drawing of the apparatus is given on Plate XVII.

The West Spring Gun was the next apparatus of this nature to be sent to France for trial, and this arrived during April, 1915. The West Spring Gun threw the Mills Grenade about 200 yards, and could throw a projectile weighing about 7-lbs. up to 80 yards, but it took two men to lift it and was large and cumbersome and generally more unwieldy than the Gamage Catapult. Only a limited number were made and issued for use.

About September, 1915, a French invention appeared which was a considerable improvement on previous patterns, and this type was asked for from England as soon as the Gamage catapult contracts had run out. The French catapult known as the "Sauterelle" weighed 53 lbs. and threw the Mills Grenade 120-150 yards, and the Ball Grenade 180 yards.

Various other catapults were tested during the Winter 1915-16, but none of these offered any great advantages over the patterns in use. Considerable improvements were made from time to time to the "Gamage" and "Sauterelle" catapults on the recommendations from Armies after trial, but during the spring of 1916, the Mills No. 23 grenade was introduced with the rifle cup attachment and except for firing the Ball grenade, the demand for catapults generally ceased.

Many designs for catapults were submitted to G.H.Q. from time to time by various inventors, most of whom were somewhat optimistic in their ideas as to the ranges obtainable from their weapons; and, as the result of experience gained in 1915, further experiments were not carried out. It was generally decided that greater ranges could be obtained from elastic slings than from steel springs, but the elastic was not durable and frequently broke.

Many kinds of grenade throwers were submitted for trial which were on other principles than that of the catapult, and inventions and samples were submitted to G.H.Q. right up to Christmas, 1918, but no grenade thrower ever realised the hopes of its inventor, either as regards rate of fire, weight, mobility or range, nor gave results comparable with those obtained in firing a grenade from the rifle.

A very clever but complicated machine in the form of a Grenade thrower, offered to and accepted for trial by the British Army, was invented by a M. Criez. Four men were required to lift this machine, which threw two Mills bombs about 100 yards. It had two long rotating arms on which the bombs were fixed, and sufficient speed being obtained, the bombs flew off by releasing a mechanism which

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was actuated by the centrifugal force due to the speed. The machine was highly ingenious and was sent to the War Museum as a relic.

Perhaps the climax in bomb throwers was reached in an invention by a gentleman, who brought to France in July, 1917, a thrower which was carried on the chest. It consisted of four magazines each containing six barrels, and which was clamped on to a breast plate strapped over the shoulders. The grenade thrown was the No. 23 Mills and it reached a range of 90-100 yards. The grenade was held in the right hand and the rod placed into one of the barrels and jerked downwards on to the base of the chamber. This action fired a cap in the chamber, and the grenade was ejected and the safety pin automatically withdrawn by a weight placed in the split ring of the safety pin. By an ingenious design of cap, the apparatus made practically no noise and was flashless. The barrels could also be fitted to be fired from the rifle if desired. Several were sent to Armies and tested, but the device was not considered an improvement on the more simple way of firing from the rifle.

The last machine of its kind for throwing bombs was submitted in January, 1919, by the Canadian Corps. The device, which was made in Army Workshops, was of a highly complicated nature, but of remarkable ingenuity. Bombs weighing 3-lbs. were dropped in at one end of the machine and ejected at the other to a range of about 800 yards at a rapid rate, after going through various evolutions inside the machine. The apparatus weighed about 40-50 lbs., but although highly ingenious, could not compare with the discharger for firing the grenades, and a range of more than 350 yards was not considered necessary for grenade throwing.

Most of these weapons were submitted to the Experimental Section for trial, but no drawings or records were preserved, as the experiments were all of a transitory nature and resulted in no permanent developments.

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ıte XV. Fig. 1.

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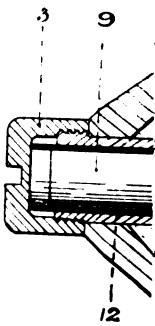

1. Body
2. Holder
3 Plug
4. Cover
5 Plu
6. Safe
7 Prim
8 Fuze

Position of the projectile
when in the Blunderbuss V

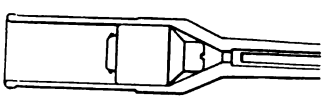

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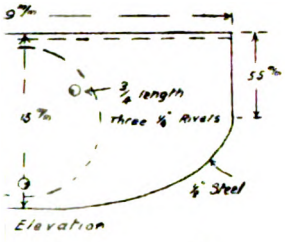
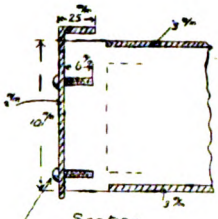
Plate XV. Fig. 1.

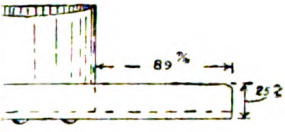
ORTAR WITH ALTERNATIVE BASE ATTACHMENTS.



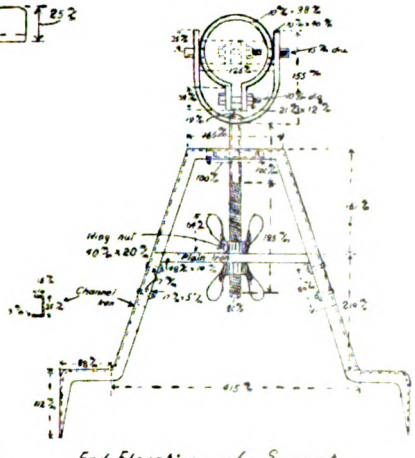
Elevation


Section

Cole Riveted, or may be secured by 1/4" rivets

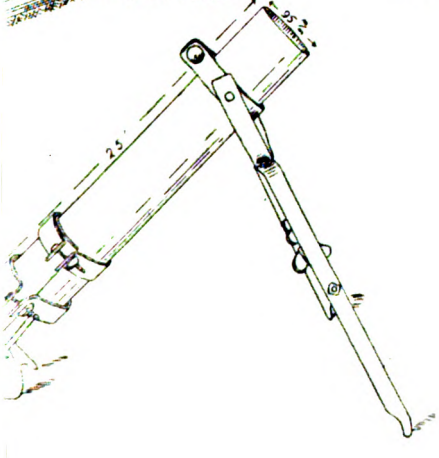


Actual Size



End Elevation of Support

Scale approx^{ly} 3/13 of actual size



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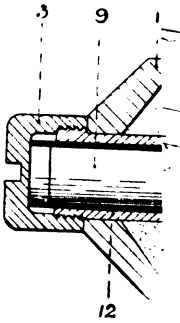

1. Body
2. Holder
3. Plug
4. Cover

5

Position

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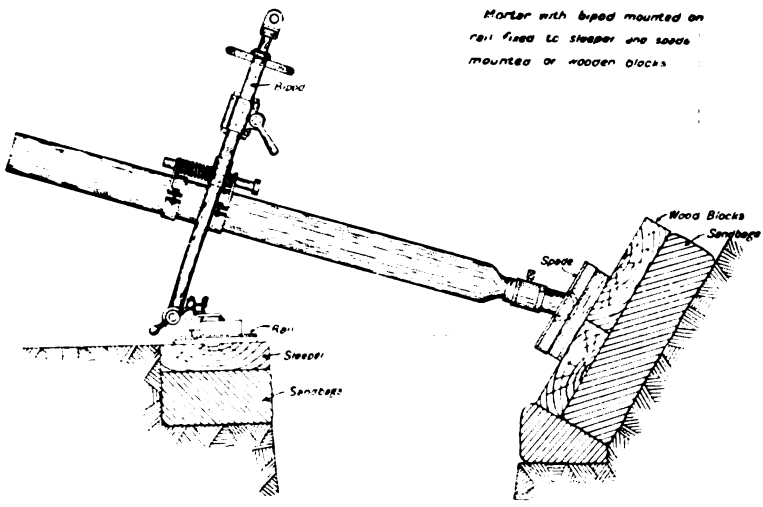
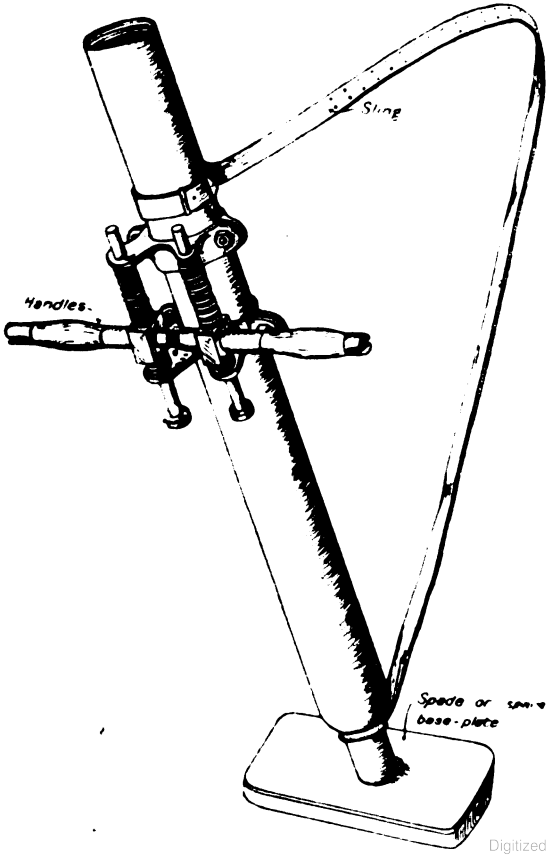
3-INCH STOKES' MORTAR

IN TRENCH OR PERMANENT EMPLACEMENT



MORTAR WITH SLING, HANDLES AND SPADE ONLY.



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3-INCH STOKES' MORTAR.

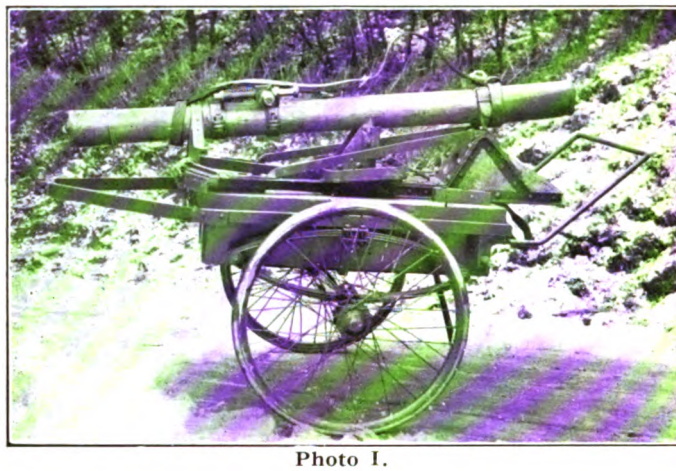

Photo I.

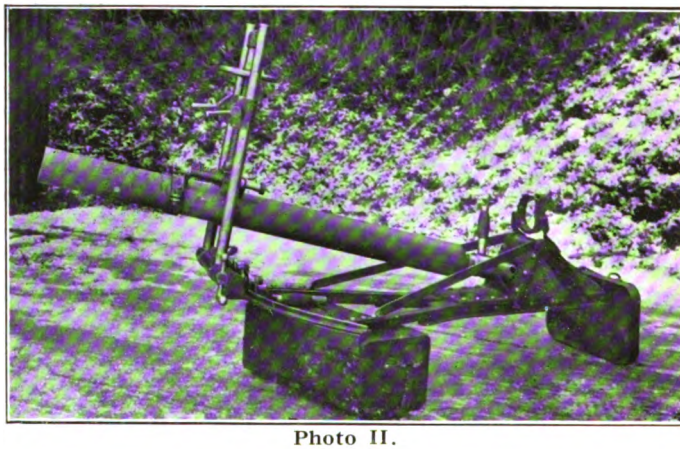

Photo II.

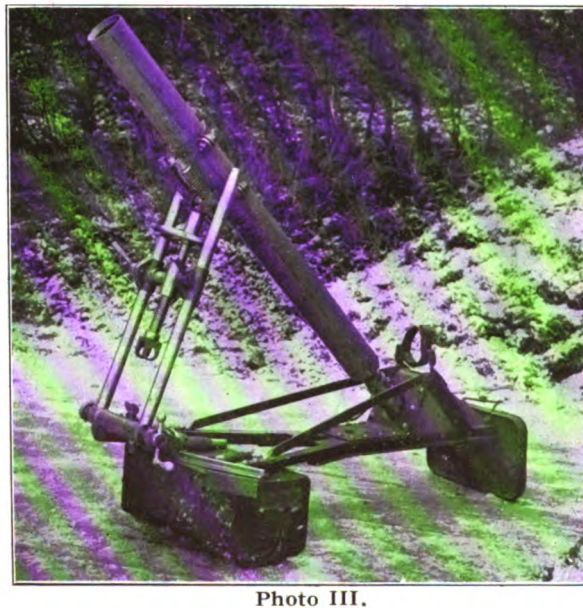

Photo III.

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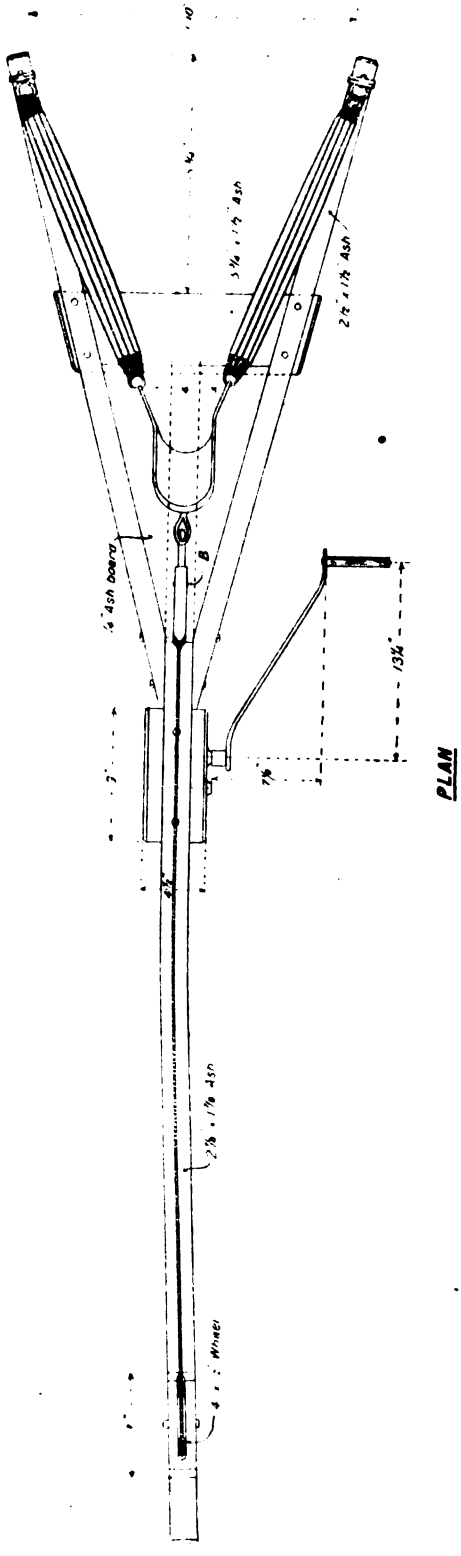

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SURVEY GRIDS AND MAP REFERENCES.

By COLONEL H. ST. J. L. WINTERBOTHAM, C.M.G., D.S.O.

At first sight there seems no justification for writing on so incredibly dull a topic as "grids." It appears, however, that there are still many who really want to know what they are, and what purpose they may be said to serve. The word itself is not very pleasant. It ought not to be necessary to go to the kitchen for an appropriate term for a method of survey, any more than it is really necessary to go to the housemaid for a term by which to label the "ancillary" services. There it is, however, and, anyhow, it conjures up a picture of a lot of lines crossing each other at right angles and forming small squares. But these squares are not necessarily on a map, and with that, we go straight into the heart of the question.

The soldier surveyor of yesterday dealt, generally speaking, with the delimination of frontiers or the mapping, at some smallish scale, of some part of the empire. He was the pioneer who built the first triangulation, and even if he had to have a fair number of points, at any rate he rarely had to think of cadastral or large scale mapping. Frequently did he have to consult the stars for latitude or azimuth, and his calculations were generally, therefore, in terms of latitude and longitude. We have all as young officers learnt to define our trig: points by latitude and longitude. P.Q.R.S. and T. have developed a new significance, and such an elementary thing as the plane rectangular co-ordinate is to most of us an unworthy subterfuge. Yet all surveyors who deal with a close network of triangulation use rectangular co-ordinates which are all "plane" in this respect, that on the map the axes, and, indeed, all x and y lines, are at right angles to each other, although they are not exactly so on the ground. They are, indeed, rectangular on the projection adopted, and here we must digress to touch on this matter of projections in order to see what happens on the ground to the lines which are at right angles on the map. The map itself is, of course, flat. To adapt it as far as possible to the earth we can roll it up into a cylinder or a cone. Suppose we consider it respectively as a plane, a cone and a cylinder, then we can project the sphere on these surfaces in the manner illustrated below:—

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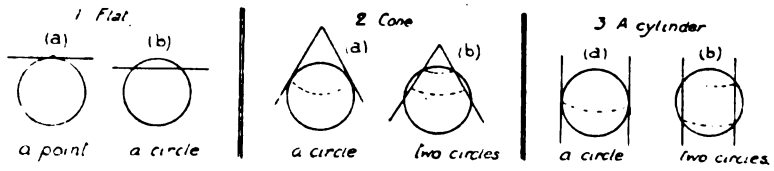

It will be observed that the earth (regarded as a sphere) may be any way up compared to the plane, the cylinder and the cone. The flat paper may rest on the north pole, on London or on Timbuctoo, and the cone or the cylinder may be fitted on with equal indifference to geography. It is to be observed that, in general, the areas or belts so represented are confined to comparatively small limits of the earth's surface. In other words, we can represent truly, or nearly so, a belt round the earth either meridionally or longitudinally or at any angle (cases 2 and 3) and alternatively a restricted area (case 1).

Where we consider two circles, as in 2*b* and 3*b*, we must keep them so comparatively close together that the bulge of the earth between them introduces no unallowable errors. Similarly, with 1 (*b*) the circle must be small enough to make it possible to map the ground included.

The subject of projections cannot, of course, be dismissed in a sentence. There are a very large number of projections, and of them some serve a special purpose and some are purely conventional. Broadly speaking, however, the conclusion we have reached is correct, and the squares (or grid) of the projection are sensibly square, too, on the ground, either on one or two circles round the earth or over a restricted and circular area. It is not necessary to *mapping*, of course, that the squares on the map should also be square on the ground. When we are mapping very large areas, such as a continent, it is not possible to make a flat and a curved surface coincide sensibly, and that is why a " grid " as we understand it must be confined to narrowish belts or smallish areas, because for our purposes of survey on the ground the " sensible coincidence " is a necessity. Supposing, for example, that the square A on the map is the graphic representation of a polygon $\boxed{X}$ on the ground. Suppose, too, an observer at the centre of X who takes his (angular) observations to the four corners. It is clear that the various sides of the polygon will not subtend 90° at his point of observation. Two will subtend more and two less. In such a case then measurement differs on the ground and on the map, and without laborious claculation results cannot be plotted on paper.

Consider the projection again. The rectangular co-ordinates on practically any projection are perfectly definite things. Any

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point properly defined as x and y on projection so and so from such and such an origin can be pegged out on the ground—but the computations are not plane, and each projection indulges in its own variety. If, however, we deal only with a small portion within or near the circles or the restricted area, the odd spherical terms tend to vanish and actually, if the small portion be small enough, they disappear entirely, leaving us only the ordinary plane co-ordinates. This is what we want ; for the term " small enough " still leaves us an area of, say, 400 sq. miles, so that the surveyor may go out with theodolite or director, may do the simplest calculation, and may plot his results directly on the " grid."

We have to consider here the fact that in serious operations hundreds of points may have to be calculated and plotted every day, and hundreds of air photographs may have to be used in mapping. As regards the computations, the easiest form is certainly the semigraphic employed by a famous computer, O'Farrel, early in the history of the Ordnance Survey, and very popular in both English and French* mapping units in the war. Observations are naturally recorded as bearings and not as angles, and the problems of intersection and resection (with numbers of bearings in either case) predominate. Co-ordinates (and in calculation they must be treated as " plane ") offer the easiest form of record, though, naturally, these " plane " computations are checked here and there on rigorously computed positions. Computations on a " geographical " basis (the graticule of latitude and longitude) may be simplified by tables and approximations, but must include three variables (the differing scales of latitude and longitude and the angle at which meridians converge).

But, of course, we cannot think " universally " in a plane, because the world is round. How large an area can we think of then ? Supposing we take case 1 and consider an area. France could be gridded after the fashion of 1 (*b*) with an outside scale error of one part in 1,040. (We usually think of one part in 2,000 as the limit we would not care to exceed.) But France's military problem, not to put too fine a point on it, is an east and west one. She prefers then to have a grid on the conical idea (as at 2 *b*) so that she may go eastwards, and, as one longitudinal projection will not carry her (within reasonable limits of error) all down her eastern frontier, she has three (and, therefore, two overlaps).

The important parts of Great Britain will go fairly comfortably on one meridional projection. Asia Minor and the Balkans, rather sketchily, on one longitudinal.

* These methods are well described in " Manuel de Topometrie " by Bailland.

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Supposing now that we are at war in any area, what has to be done before our grid is ready? In this area there will be some existing maps and consequently some sort of survey, even if only a few latitudes and longitudes. The first thing to do is to choose a projection and grid which will be suitable to the anticipated magnitude and direction of operations. The second is to convert all survey data to terms of the projection chosen. We are, then, ready to carry on fresh intensive and rapid surveys. There is a good deal of preliminary computation to do in most cases, and the more fortunate we might be in finding data the more computation is involved. Our expedition to Italy in 1917 was a case in point (for the Italians did not use a grid).

So far we have not touched the matter of reference on a map. It is not, indeed, absolutely necessary that there should be any direct connection. It is possible to think of a gun as being x' and y' on the grid projection and at M 35 *d* 34 on the map. This is, of course, what we did on the western front (there was a connection in this case, but an obscure one).

Purely and simply as a system of reference our system on the Western Front was a very good one, and had the great merit of causing considerable bewilderment for a time to the Germans. But it is, of course, a great simplification to combine the "grid" and the "reference" if you can. We intend to do so. But here we come up against a very prevalent and quite mistaken idea—namely, that the adoption of a grid on a new projection *ipso facto* makes all existing maps obsolete. Nothing of the kind. In Italy, for example, we had a map on a polyhedric projection overprinted with the grid of a Lambert orthomorphic projection. The explanation is simple. The "squares" and "lines" of a grid on any suitable projection may be identified on the ground. We might even trench or spitlock them out. They would not, of course, be *quite* square, but sensibly so if we are near our circles, and they will be quite definite in relation to any detail. They can thus be mapped at will on any other projection. It would, of course, be quite possible, if this second projection were a badly distorted one, to have the grid lines, as plotted on it, sensibly curved, and the squares far from square. In practice, however, this does not occur on topographical maps at the scales we use for military purposes. One may say that all topographical maps are nearly, if not quite, sensibly and plottably correct (if the original survey was correct).

We deal then in three things—two projections and the earth's surface—all sensibly coinciding (in the restricted area we consider) and on all three will the "grid" be sensibly correct at our scale. One might, then, ask, why introduce a new grid projection if the existing map projection is sensibly the same graphically. The

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answer is that we have to be much more precise than measurement on a map will permit of. Many projections, sensibly accurate on paper at some such scale as one inch to the mile, are inaccurate enough to make quite unallowable differences between *angles* computed from the projection co-ordinates (treated as plane) and angles measured on the ground. Such was the case with the 1/80,000 of France (on Bonne's projection).

Just one final word on this projection question for those who know something of the subject. An "orthomorphic" projection is one which has the property of showing angles true all round any one particular point (if the rays are not too long). This is a most important factor in maintaining a close connection between field measurement and computed result. We like orthomorphic projections, therefore, even if they are not absolutely essential. The United States grid is an exception, for it is arranged on the polyconic projection used there for mapping (there are seven overlapping meridional strips), whereas France, Germany and ourselves use orthomorphic grids for preference.

Supposing, however, that the problem confronting us consisted merely of some small war or minor operation with little artillery and less survey method. Any system of reference would do. It is easy enough to evolve a good one, and one which will deal not only with the narrow belts and small areas necessary to the introduction of a military grid, but one which would be of universal application.

Such a system could not, however, be founded on lines at right angles or squares, and, therefore, could not lend itself (at any rate, in high latitude) to the use of co-ordinate cards.

In conclusion, let us dispose of one or two questions about the grid which have from time to time, arisen.

The Name. The French were the first to use the grid as a basis for reference. They used a form of reference somewhat like our present form. This system was modified by us in Italy, and modified once again by inter-allied agreement in 1918. Since then we have modified it a third time and the French have returned to their original form. Our grid is not, therefore, French or Allied. Again, the word Lambert is often used. The distinguished old Geodesist, who evolved the projection which we used for our first grid (but do not use in England), would turn in his grave at the thought of using plane co-ordinates on his projection—and, in any case, was not concerned in grids. Let us be content to call it the British grid.

The Origin. Certain enthusiasts have chased the origin of numbers on our grid to its ultimate home in the Atlantic, and are perturbed apparently at its forlorn and undefended position. Thoughts of Coast defence, of perhaps a mixed detachment, seem to have been entertained. The real and important origin for surveyors must always be more or less central, however, and the

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"false" origin may be anywhere so long only as we remain in one of the quadrants formed by the axes (in order not to change sign). There is no theoretical reason for remaining always in the N.E. quadrant (with co-ordinates increasing to the east and north). In Malaya, for example, it would be more convenient to increase west and north, and even in England a false origin up Iceland way, so that co-ordinates increased south and east, would perhaps be more convenient. But we must make some concession to precedent and tradition—and so far, then, we have arranged matters so that the false origin lies west and south.

The Size of Square. For general purposes of reference it is a matter of indifference what unit is employed. We want a square of a suitable size, of course, not too large to forbid decimal division by eye, and not too small to necessitate obscuring the map with lines. But whether it be metres, yards or even parasangs matters little.

It may be possible for a tank to pursue its unflinching path along a grid line. For most of us it is not possible, and we do not, therefore, measure distances along them. For the surveyor, either of the Corps or of the Regiment, it is important that the unit should be that employed in the survey of the country. In other words, for the grid we must have a convenient survey unit, for reference the point is immaterial.

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A FERRY IN NORTHERN IRAQ.

Mules and stores leaving shore. Disembarkation point is just under Quwair village, visible on right.

Mules disembarking.

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A FERRY IN NORTHERN IRAQ.

By MAJOR R. HAMILTON, O.B.E., R.E.

IN March, 1923, a column of infantry, pack artillery and sappers set out from Mosul for Southern Kurdistan, the sapper unit concerned being No. 63 Field Company, Q.V.O. Madras Sappers and Miners. The chief engineering operation that had to be performed was the ferrying of the force across the Greater Zab River at Quwair on the way to Erbil, and of this operation it is proposed to give a brief description.

The Greater Zab is the largest tributary of the Tigris, taking its rise in the mountains between Lakes Van and Urumiah. Like the Tigris itself in its upper reaches, the river bed is a wide uneven stretch of shingle, over which the river normally wanders in one or more channels. In the case of flood, caused by rain or melting snow in the hills, these channels expand, covering more and more of the shingle. The highest floods are liable to occur in the early spring, when the two causes are combined, a heavy fall of " warm " rain greatly increasing its own volume of water by the accumulated snow which it falls upon and melts.

As luck would have it, such an occurrence took place just as the column reached the river. There had been heavy rain for some days and the whole expanse of shingle was covered from bank to bank, so that one looked out upon an unbroken stretch of half-a-mile or so of brown, roaring, icy cold torrent. Getting the column to the other side did not promise to be easy.

The craft available were as follows :—

(1) Four boats from local ferries.

One was a large unwieldy boat which would take two or three vehicles, but was not considered safe to work in high flood. The other three were for animals, with blunt bows cut down almost to water level, over which animals are walked in and out. Each would take six or seven horses or mules, but they were in very bad condition and generally only one or at the most two were available for work.

(2) A fleet of some 21 boats brought from Mosul. These were of the type seen in the photographs and were of exceedingly primitive construction. They had to be relied on, however, for most of the work.

(3) Four bays of light bridge with the Sapper Company (British pattern pontoons and superstructure).

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(4) Two motor launches which arrived after the first two days.

(5) A "kilik" or skin raft obtained towards the end of the operation.

The boats had to be towed a long distance up stream on each bank in order to make their landing point on the other side, the "round trip" taking from 1½ to 2 hours.

Besides men and stores there were some 1,640 horses and mules and 68 vehicles, mostly G.S. and Ambulance waggons, to be got across.

Men and stores offered little difficulty. Each Mosul boat could take about 20 fully equipped men or an equivalent weight of stores. The launches, when they arrived, were also used for this.

The difficult problem was to ferry the animals and vehicles in a reasonable time.

Of the animals, about 900 to 1,000 were small pack mules, and it was considered too risky to try to make them swim such a long distance. The ferry boats could only deal with a few animals and were reserved mainly for horses. The only method for the small mules was to take them in the boats from Mosul. Accordingly piers were built of sandbags and brushwood to a height just above gunwale level, and the boats brought alongside; brushwood was strewn on the bottom of the boats to form a cushion. Mules were then brought along the piers and made to jump in. It was found that four could be got into a boat, standing side by side athwart the boat.

The whole proceeding was viewed by the boatmen with the deepest gloom and, indeed, to see mules alighting on the boat floor with sickening crashes and then doing their best to kick out the sides, or jump out again (which latter they often succeeded in doing) made one wonder how long these very flimsy craft would survive. A small mercy was the fact that the mules almost always quieted down when well away from shore. Still a passage by "cattle-boat" was never a really dull experience.

Leaks, of course, began almost at once, and after the first day or two a number of boats were always out of action and under repair. Only one actually sank in midstream and that very fortunately on a shingle bank in shallow water so that men and mules were safely rescued. The transport of animals never stopped, however, and about 300 a day were ferried by this means without losing any, and the transport of men, stores and ration sheep went on at the same time. The light draught waggon mules and most of those of the Pack Battery were too large to travel in the Mosul boats without great likelihood of capsizing and it was evident that they would have to be swum. This operation was not begun till two or three days after the ordinary ferrying had been in progress;

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the water level had subsided a little and an island appeared which could be reached from the near bank by fording; this island was made the starting point, thus shortening the journey somewhat. There was still a distance of several hundred yards to be swum, however, and this combined with the swiftness of the current prevented any chance of letting animals swim free. They had to be swum from boats and the great necessity was to get a good start.

The following method was evolved. A place where the bank shelved steeply was chosen, so that the mules could be launched more or less directly into water out of their depth. A boat was held bow outwards at right angles to the current by a rope from the bow to the shore upstream. Mules (or horses) were taken in threes; they were brought to the edge of the bank upstream of the boat, and their drivers, one to a mule, got into the boat, holding the head ropes, which had to be specially long ones. A 3-in. rope was passed behind the mules' hindquarters and when all was ready this rope was pulled forward and the mules were driven and pushed into the water; the rope to the bow was let go the instant the mules were in, and the boat started off.

If there were any hitch in getting the mules properly into deep water they would hold back the boat, the bow would swing downstream at once and everything would have to start again. Sometimes the mules would all combine to turn and swim for the near bank, in which case they always defeated the rowers and brought the boat ignominiously back a long distance downstream. Generally speaking, however, the method worked quite well. Four mules died, owing to the drivers holding the head ropes so tight that the mules could not swim freely and were completely exhausted by the time they reached the other side.

To turn to the vehicles. These were taken (*a*) by the big ferry boat, (*b*) by an ordinary pontoon raft, and (*c*) by *kilik*. The last is worthy of remark. The two *kilik* men arrived one morning with an unostentatious little bundle of only 100 goat skins and some thin poles, twine, etc. By evening they had blown out their skins and made their raft, which, after decking with a few chesses, was found fully capable of taking an empty G.S. wagon. On the Tigris very large rafts are made on the same principle. Thirty-one vehicles were ferried in a day by these various means, though this was at the end of the operation when the water had dropped considerably.

A remark may be made about towing the various craft. The Arab boatmen were always supplemented by military fatigue parties, but even so, towing by hand against the heavy current was slow and laborious. It was found that much time could be saved by using the wagon mules for towing. Special

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rope had to be provided, as the local towing ropes could seldom stand the strain! Also the speed of the boat relative to the water had to be carefully watched, the large ferry boat being swamped and sunk on one occasion by being pulled too fast. It took a considerable time to salve.

No accidents to personnel occurred in the actual process of ferrying, but there were two mishaps to sapper parties, one while engaged in trying to get a cable across a very rapid channel and the other in trying to salve the pontoon lost on the first occasion. A British Officer and some 18 sappers altogether were immersed and carried away a long distance downstream on the two occasions, but all kept afloat and were eventually rescued (though in a half frozen state), except, unfortunately, one sapper, who completely disappeared.

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NOTES ON CEMENT CONCRETE WORK IN THE FIELD.

By LT.-COL. D. K. EDGAR, D.S.O., R.E.

THE use of cement concrete in constructional engineering is extending year by year, and, with the improvement which is taking place in the manufacture of cement and the production of rapid hardening cements, it is safe to say that its importance will increase.

It is recognised that full value of cement concrete cannot be obtained without intelligent supervision during mixing and placing, and that the best results are obtained by trained gangs of men well organised and drilled in their duties. Concrete can be laid by unskilled and unexperienced labour, but the results obtained are not as consistent, nor is the work as economically carried out.

From a military standpoint concrete has assumed great importance, and will become more important when a supply of slow setting, rapid hardening, cement can be assured.

To obtain the best results from a cement it must be slow setting; for it is quite conceivable that under certain conditions a period of an hour or more may elapse between mixing and placing the concrete. It must be rapid hardening, in order that the concrete may be taken into use within a day or two of placing.

There are certain brands of cement on the market which claim the above attributes, and there is very little doubt that an ample supply of suitable cements will be forthcoming in future. Good cement being assured, how can the best use be made of it?

Intelligent supervision is essential, and men must be trained in peace time for this duty. Supervision does not mean only the ability to see that the correct amounts of material are measured out and mixed, but it should include the recognition of suitable aggregates for concrete, the knowledge of the dangers involved in the use of dirty or unsuitable sand and stone, and the capacity for organising the labour and the supply of the raw materials.

Trained gangs can be obtained on service by keeping the same units on concrete work. In April, 1918, two Post Construction Companies were lent by the Director-General of Transportation to the Engineer-in-Chief for concrete work, and later on in the same year five Transportation Works Companies were formed for the purpose of erecting standard concrete block pill boxes, and other reinforced concrete work. The evolution and design of these concrete block pill boxes is interesting, but cannot be described in detail here. It will be sufficient to say that they were built of perforated concrete blocks,

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made in a central factory and shipped with the necessary reinforcement to the site of the works. The concrete blocks were threaded on to vertical rods and were so arranged that a horizontal bond was given. The whole was then grouted up and produced a more or less monolithic blockhouse.

The obvious disadvantage of this method of construction is that for a given thickness of wall, its strength is not equal to that of mass concrete, and, to produce an equal strength would require a greater thickness, and, therefore, more material and transport. Much work was done during the war with mass concrete *in situ*, with excellent results, but such difficulties were encountered that for rapid erection of M.G. emplacements the block concrete system was evolved.

The difficulties met with are tabulated below, and suggestions made of how they might be overcome without resorting to the block type of construction :—

(*a*) Great difficulty in transporting the material to forward sites ;
(*b*) Necessity for keeping the various ingredients (aggregate, sand and cement) clean and in good condition—cement especially suffering from the inevitable exposure to damp ;
(*c*) Delay during construction in erecting shuttering and strutting, and waste in striking on completion. Timber could rarely be used more than once, and there was always a shortage ;
(*d*) Length of time required for setting and maturing ;
(*e*) If reinforced, great difficulty in placing and fixing reinforcement under trench conditions—often by night ;
(*f*) Difficulties of concealment—concrete became very obvious if earth or other covering was destroyed by shell-fire. During construction it was not easy to conceal the materials, mixing boards especially showing up to aerial observation ;
(*g*) Lack of practical experience in the work on the part of the majority of engineers.

In all cases material will have to be brought forward by rail or mechanical transport, and, provided that the walls of the structure can be made thinner with reinforced mass concrete than with concrete blocks, the gross tonnage to be transported will be less. Material in its raw state is more easily handled than concrete blocks, and damage due to careless handling is avoided.

With slow setting cement it is unnecessary to mix the concrete actually on the site of work, and materials can be collected and camouflaged at any convenient spot. If possible, a battery of mechanical mixers should be installed, and the mix distributed by Decauville to the works, which apparently was the system whereby many of the German defences were prepared. If this is not feasible a mechanical mixer mounted on a caterpillar truck, accompanied

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by sufficient raw material for a night's supply, could carry out work at the spots not served by Decauville.

The point being that it is no more difficult to transport the raw material to site than it would be to transport completed blocks.

Even if materials have to be man-handled, the mixed concrete (gauged with a minimum amount of water) or the raw sand, aggregate or cement could be packed in sandbags and made up into one man loads for transport.

The second difficulty, especially as regards cement, is more serious. Any rough flooring (or tarpaulins) is sufficient to keep the sand and aggregate clean if stacked on muddy ground, and it is unnecessary to protect it from the weather. With regard to cement, sufficient protection for a few days can be given by tarpaulins above and below the stack. Such stacks of materials should not be difficult to screen from observation, and present no more difficulties than stacks of concrete blocks.

With regard to shuttering, good workshops and preparation will go far to solve this difficulty. There is a means, however, of incorporating the block system with the concrete *in situ* and dispensing with the shuttering. It is a common practice in concrete work to build 4½-in. brick skin walls, and after every foot of walling to fill in with concrete, the walls being bonded every fourth course into the concrete by headers. By substituting for the bricks suitable pre-moulded concrete blocks, which will take the necessary reinforcement rods, it should be possible to dispense with the shuttering. It appears, however, that in the majority of situations, suitably designed panel shuttering should be better, and with a well-trained gang the time spent on erection and the wastage when removing should be reduced to a minimum.

In a pamphlet recently issued by a foreign power it was stated that such shuttering could be used four or five times over. The planking on the interior walls might well be left in position, fixed to dovetailed battens embedded in the concrete. If this is decided upon it will only be necessary to remove the interior struts, and will avoid the necessity of taking large panels through a tortuous opening. Some of the advantages of a wooden lining compared to a concrete surface are obvious, but one which might escape notice is the protection given to the occupants from injury from flaking concrete dislodged by the concussion from a direct hit.

The support of a heavy roof during the laying of the concrete is a problem. Wooden shuttering well strutted, similar to that for the inside walls, would do, but probably the most simple method is by shallow and broad R.S.J.'s, spaced about 6-in. apart flange to flange, the intervening spaces filled in by planks resting on the lower flanges; the R.S.J.'s being built into the roof.

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The time taken for setting and maturing of the concrete should not cause any difficulty in future with the use of rapid hardening cements. Reinforcement is essential if the bulk of the concrete is to be reduced. During the late war the figures adopted for the thickness of concrete required to resist an 8-in. shell were, for plain concrete, 5-ft. and, for reinforced concrete, 3¼ ft. Owing to the greater strength of the present-day concrete, it is probable that these figures can be reduced, but the proportion between plain and reinforced concrete will remain much the same.

If reinforcement is used, all bars must be cut to length and bent as required before being sent to the work. Templates should be prepared for the accurate and rapid spacing of the rods, and the amount of work required to be done on the site reduced to a minimum. Drill and practice in placing the reinforcements, combined with complete preparation of material, will do much to overcome the inherent difficulties. It should not be more difficult to conceal concrete work than many other engineering works which have been successfully camouflaged. After a pill box is completed it should be immune from anything except a direct hit by a heavy shell or bomb. It is during construction that the greatest difficulty will occur. The quicker the work can be carried out, the less chance there is of discovery. Mixing concrete by hand on mixing boards is a slow and cumbersome method, and will seldom have to be resorted to if concrete mixers are available. There are many suitable batch mixers on the market at present, and it is reasonable to assume that sufficient for all purposes will be obtainable on service. Light mobile mixers mounted on their own caterpillar trucks would be suitable for forward areas, while larger ones will be required forther in the rear.

Since the war much attention has been paid to the use of concrete and much experience has been gained, but experience under service conditions is difficult to obtain in peace time. Concrete is an expensive material to expend, and any peace time jobs requiring concrete work must be carried out under peace time conditions, and not as on service. At the front, much of the concrete work will have to be carried out in darkness, and it is well-nigh impossible to do this on a peace time job.

If a standard reinforced concrete machine gun emplacement were approved, much could be done towards the training of the supervising concreter in this class of work. The shuttering could be prepared and fixed by night ; a proportion of the reinforcing bars cut and bent to shape and fixed in position by night ; and, finally, batches of gravel and sand could be mixed and placed between the shuttering without destroying the value of the material.

It is not only pill boxes which will be constructed of reinforced concrete, but this important service has been used to illustrate

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the lines on which concrete work may proceed in war. Three things are necessary for effective and efficient work—(*a*) Standardization of designs, whether for roads, pill boxes, dug-outs, culverts, or bridges, etc.; (*b*) Good equipment and organisation for producing masses of concrete quickly where required; (*c*) Trained men who know their jobs.

Much of the information regarding the concrete work in late war was obtained from an article on *Work in the Field under the E.-in-C., B.E.F.—Concrete Defence Works and Factories*, which has been written as a part of the series, *The Work of the Royal Engineers in the European War*, 1914-19. It is hoped that the publication of this article will not detract from its interest when it is eventually published.

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SOME REFLECTIONS ON FRONTIER WARFARE.

By L.D.G.

When the increase of power and mobility that science has given to the Army is realised, and then when one reads of the vast increase in the cost of defending the nation's frontiers, it is difficult not to wonder what is wrong. If we allow that our opponents' armament has improved to the extent of the difference between the *jezail* and the modern rifle, how is it that with motor cars, aeroplanes, light and heavy machine guns, hand grenades and artillery we have not made frontier warfare a much easier business?

One idea to be set forth in these notes is that some modern developments are, in this type of fighting, an actual handicap, as at present used, and that others are not adequately employed.

In what might be described as the pre-scientific days of frontier fighting the forces employed were in numbers not dissimilar from the expeditions of the last few years—if anything they were less. The armament was poor on both sides with, say, a five to three advantage to us. Discipline was, of course, excellent. Movement was not much slower than to-day. The opposition was good, but it has learnt a certain amount, though not much compared with what the British forces have, or should have, learnt. The results were very similar to those recently achieved at a far greater cost in money and a similar cost in life.

From the above must we assume that frontier fighting has not developed in the last fifty years? If we make this assumption, the question then arises, why has it not developed, and what can be done about it?

The reason that appears first is that as new weapons have been invented they have been immediately introduced on the frontier without a thought of whether they give a return of power commensurate with the extra trouble and hindrance to movement they involve. In other words, the old maxim that success in frontier fighting is measured by the speed at which certain (sure) movements can be made, has been forgotten and the ratio between the mobility of the opposition and that of ourselves has not materially altered. Hence, for our success we still pay as high a price as ever.

In order to study the factors that affect mobility, and to evolve an idea of frontier fighting, which it is hoped may lead to an improvement on present methods, let us re-state some axioms:—

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(*a*) A force against normal tribal opposition can defend itself, and provided with food and ammunition, it is independent of L. of C.

(*b*) For any given standard of mobility the safety of a force as a whole is inversely proportional to the amount of transport required to maintain it.

(*c*) The cost of a force is proportional to the amount of transport required to maintain it.

(*d*) The effectiveness of a force is proportional to the square of its safe speed.

(It will be realised that the only novelty in the above axioms is the wording. They are in all text books.)

We are, therefore, met with the task of :—

(1) Increasing mobility.

(2) Decreasing transport.

(3) Decreasing cost.

If we can reduce transport, much will be achieved. The force will be able to move quicker and, therefore, will be more effective and safer. The cost will be less, and few, if any, geographical barriers will prevent its arrival.

The transport carries rations (men and animals—the latter a very, very heavy item) and ammunition forward and casualties backward. The quantity eaten by the man cannot be reduced by any serious amount, though the leisurely progress of grazing herds may be a serious slowing factor to a force. The number of animals required to be maintained with a force can, however, be reduced.

The amount of ammunition to be carried is the next point. In view of the difficulty of dealing with this point and all it involves without coming into conflict with many official *obiter dicta*, let us look for a moment at the bare necessities of a force. Our modern rifle has lost the, say, 20 per cent. advantage that our former weapons held over the *jezail*. The Lewis gun, however, more than replaces this. Is the machine gun, then, necessary? If it is, can the Lewis gun be dispensed with in this type of warfare? Both are ammunition eaters of a high order even when used with the minimum wastage of effort. The machine gun has, of course, long range but heavy weight, it is not a quick weapon in hills, though its power is prodigious.

The Lewis gun, on the other hand, is light, but is heavy enough to require a mule for normal transport. It is a quick weapon even in hills and its fire power is, for the majority of cases that arise, more than adequate. Before, however, ruling the machine gun out for an ideal frontier column and realising that it is a factor

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which most commanders will be very loth to discard, is it not possible that, anyway, its daylight role might be performed by another agency—the aeroplane? In operations in Kurdistan with a column of levies whose equipment of machine guns was, according to most ideas, inadequate (though their knowledge of mountain warfare was good) a system of employing aeroplanes in this connection was evolved. Each section had with it three strips of white calico. When it was about to picket a hill it put these out at its base in the form of an arrow pointing upwards. One of the aeroplanes that was co-operating with the column then machine gunned the top of the hill in question and thus was able to provide covering fire. On the arrival of the picket at the hill top three white strips were put in a triangle signifying that that hill was held. Just before retiring the strips were changed into the form of an arrow pointing downwards and an aeroplane then flew low over the place to tackle any opposition that tried to rush. This worked excellently, and the lack of active opposition, though not absence of opponents, was considered a measure of their dislike of low-flying machines.

The machine gun, therefore, may be given wings and eliminated from our ground force, and with it vanish many mules.

And now for the man's load. Most of those who have attempted a running climb of a considerable height will agree that a pair of shoes and a *topee* constitute the ideal kit. Between the ideal, however, and the present outfit is it not possible that a mean may be found? Rifle, bayonet, water-bottle and ammunition are unchallenged necessities.

The present form of ammunition boot is heavy, and it is possible that a form of shoe like the Richachatar might be adapted for service use. Climate must count to a large extent, and the question of shorts *v.* trousers is debatable. Tunic and jersey are necessities; and possibly a clean shirt and socks. Ground sheet and overcoat are a heavy handicap to mobility, though essential at nights. Blankets and tents for suitable native troops are not essential for periods up to two months—this is experience, not theory—even with bad weather (rain and slight frosts). The omission of blankets removes the necessity for a quantity of transport. The carrying of overcoats and ground sheets not on the man improves his mobility enormously. The transport required, however, is heavy. It is possible that a compromise might be arrived at and that the overcoats, etc., of only those troops on very active climbing employment need be provided for.

But these considerations, though important, are secondary compared with the elimination as far as possible of the forward cartage of food and ammunition on pack animals. A striking force of 7,000 men and 1,000 animals will require about 24½ tons a day,

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allowing for an expenditure of 200,000 rounds S.A.A. and 600 rounds of 3.7 Howitzer.

These figures will be criticised as including an undue expenditure of ammunition and too few animals. The second point will be dealt with shortly. If this expenditure of ammunition is excessive so much the better.

To carry 24½ tons requires about 350 animals (at 2 maunds each) and, allowing for a much lower expenditure of ammunition, it is clear that loads for at least 300 animals must be with the column per day. These in turn require feeding, and so the game goes on. Is there no better way of supplying troops in difficult country than the inefficient pack animal? Good roads would make supply by armoured lorries or caterpillar vehicles, in most cases, possible. Roads, however, are usually not available and, anyway, cannot be counted on. The remaining possibility is the air.

Rationing by aeroplanes in bad country is almost impossible. It has been tried several times—once recently,—but never with any real success. The remaining method is the airship. The type of airship required does not at the moment exist, as the types so far built have been evolved with different ends in view. That such a type is a perfectly practicable and cheap proposition has been stated by experts in this branch of air work. Its journeyings would be at night, when heat did not cause bad atmospheric disturbances and navigation would be comparatively safe. The size suggested is a useful dead load of 5 tons, speed 35-50 m.p.h. No great performance is required, though ease of manipulation and adequate engine power are essential. One original machine of this type can, it is understood, be constructed for about £50,000, or about the cost of four Vickers-Vernon troop carriers, a figure which would be reduced on duplication of orders.

It is realised that difficulties would be encountered and risks be run by the crew. But in man-power units it means risking, say, two or three crews of five against all the equivalent personnel of convoys and pickets, and, in addition, a saving in cost, direct and indirect. The former (direct saving) on cartage costs, including the guarding of convoys, for which must be allowed 400 men per mile (Waziristan figures) and the latter (indirect saving) on the extra speed, and so the smaller time required for a striking force to reach the seat of the trouble, and, therefore, the increased chance of localising it. (Approximate comparative cost figures are attached, Appendix A.).

To sum up. We have at our disposal weapons which have increased our striking power enormously. Inability to use these means that we are not reducing the costs of frontier warfare—in men and material—rather they are increasing. With the present need for economy, to fail to " make the best use of the Army allowed

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With the increased mobility of the column, due to no land L. of C. (incidentally all communications by pick-up message or wireless), the cost of L. of C. would be reduced from £9,470 to £2,100 per day. A not inconsiderable saving. The indirect savings in cost, due to more rapid consummation of the required object and the localising of disturbances, and the reduction in casualties due to increased rapidity of movement, cannot be calculated, but there seems little doubt that they would be considerably larger even than the direct costs.

The cost of other aircraft co-operation is not easy to arrive at. A figure which is official, but is regarded as very high (it includes a portion of everyone's pay and maintenance from the squadron *dhobi* to (probably) the Prime Minister) is £10 per flying hour per machine.

Allow eight machines continuously co-operating with the force for 12 hours a day, *i.e.*, say, half hour out, two hours co-operation, and half-hour back to re-fill, overlapping, gives 18 hours flying for a 12 hours' co-operation, *i.e.*, 144 machine flying hours, if eight machines are required.

Cost = 144 x 10	=	£1,440 per day
Cost of Air L. of C.	=	2,100
Total daily Air cost	=	£3,540

From this must be deducted the cost of maintenance of machine gunners with the column, but even allowing this, a saving of £6,000 a day should be made.

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THE SIEGES OF ALEXANDER THE GREAT.

By COLONEL J. F. C. FULLER, D.S.O.

1. THE ENGINEERING SKILL OF ALEXANDER.

Military history provides the student with many examples of specialist generals, great infantry or cavalry leaders, great artillerists or engineers, but the few really great soldiers who have risen to be captains of the first rank, have to all the qualities of these specialists added a general grasp of war which has enabled them to use all the means at their disposal as an artist uses his tools. Amongst these great captains none have excelled or even approached Alexander. Whatever he does, he leads by a long length; whether it is as a commander of infantry, or cavalry, or as a besieger of fortresses and cities. In all branches of war, his genius is supreme, and the greater the difficulties, the more eager is he to accept their challenge.

In days when battles were won not by fire power but by assault, to defeat an enemy who occupied a defended camp or fortified town was always a difficult operation, as difficult as was the storming of trenches during the first three years of the Great War of 1914-1918. Yet, no fortress defeated Alexander, and some of the fortresses of antiquity were such as would have struck consternation into Vauban. The walls of Carthage were of terrific strength; in its hey-day Babylon was surrounded by a bastioned wall, reputed to have been 300 feet high and 70 feet thick; Ecbatana possessed seven walls, and lesser cities of importance stout ramparts.

The main sieges undertaken by Alexander fall into two groups—the coastal fortresses and the mountain strongholds. The first includes Miletus, Halicarnassus, Tyre and Gaza, the second, the Sogdian rock, and the rocks of Chorienses and Aornus. Besides these two groups, he also besieged Thebes, and, when in Scythia, Cyropolis, which he took in the same manner as Cyrus took Babylon, that is by entering the town by wading along a branch of the river (Jaxartes) which flowed through its fortifications.

2. THE FIRST PHASE OF THE SIEGE OF TYRE.

Of the first group I will only deal with the siege of Tyre, which was not only by far the most difficult siege undertaken by Alexander, but also one of the most extraordinary sieges in history.

The Phoenician cities formed a league much like the Hanseatic league in the Middle Ages. They owed allegiance to the Great King, but were semi-independent, for the Persian monarchy relied

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largely on their good will for seamen, ships and trade. Between them reigned persistent jealousy and this greatly assisted Alexander in subduing them. On his southwards march from Issus, the first city to surrender to him was Marathus, then Byblus, reputed to be the most ancient city in the world, capitulated and so also did Sidon out of jealousy for Tyre.

As Alexander neared Tyre, at first the Tyrians were undecided whether to admit him or not. If they opened their gates to him, and should he eventually be defeated by Darius, they would have to pay a heavy fine, they were Shemites and they loved the feel of gold.

Alexander asked permission to enter the city in order to worship in the temple of Hercules, but the Tyrians smelt a rat, and suggested that the temple on the mainland would equally well satisfy his devotions. Alexander could not, however, leave this fortress untaken. If he passed it by, the cities north of it would revolt and those south of it refuse to surrender. Further still, Tyre must be his, its occupation was essential to his plan, for without it he could not gain command of the sea.

The Tyrians now point blank refused to open their gates, and this was easy enough to do, seeing that New Tyre was built on an island, about one mile in length, and half a mile from the mainland, on which the old city stood ; further Alexander possessed no fleet.

To an ordinary general, situated as Alexander was, the reduction of Tyre would have appeared an impossible task, even the old city had withstood Nebuchadnezzar for thirteen years. But Alexander was no ordinary general nor was he a Nebuchadnezzar ; he was Alexander faced by an island fortress with walls in places 150 feet high, manned by a brave people of intelligence and resourcefulness, holding command of the sea and determined to defend their city until Darius and his millions could once again sweep down on the rear and flank of the Macedonians.

Possessing no fleet, Alexander determined to build a mole from the mainland to the island. He forthwith demolished Old Tyre and, by impressing thousands of its inhabitants, " raised a mole two hundred feet in breadth." (1) The construction of this immense work is interesting. Arrian tells us : " The place is a narrow strait full of pools ; and the part of it near the mainland is shallow water and muddy," but the part near the city itself, where the channel was deepest, was about three fathoms in depth. But there was an abundant supply of stones and wood (2) which they put on the top of the stones. Stakes were fixed down firmly in the mud, which itself served as a cement to the stones to hold firm. (3).

(1) *Diodorus* XVII, IV.

(2) According to *Curtius* IV, 10, the wood came from Lebanon.

(3) " Arrian " II. XVIII.

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At first the Tyrians treated the whole proceedings as a joke and asked Alexander "Whether he supposed himself to be stronger than Neptune." Then, as the mole advanced, they grew nervous; one dreamt that Apollo was about to forsake the city, and the others, determining that he should not do so, "fastened his image to the pedestal with golden chains." Having thus regained their courage, they sailed round the mole "and made it impossible in many places for the Macedonians to pour in the material." To counter these attacks, Alexander constructed two wooden towers at the end of the mole and in these he placed his engines of war.

3. The Second Phase of the Siege of Tyre.

Apollo now being quite incapable of leaving the besieged city, and a whale having been washed up against the mole, which the Tyrians imagined was Neptune himself, a series of most astonishing counter-attacks was launched. First "they filled a vessel, which had been used for transporting horses, with dry twigs and other combustible wood, fixed two masts on the prow, and fenced it round in the form of a circle as large as possible, so that it might contain as much chaff and as many torches as possible. Moreover, they placed upon this vessel quantities of pitch, brimstone, and whatever else was calculated to foment a great flame." (1). This fire-ship they launched and set the wooden towers alight, and, under cover of the confusion resulting, they put to sea and attacked the mole.

The devices made use of by the Tyrians are of great interest. Chemical warfare was employed, for we learn that pots of burning sulphur, naphtha and oil were hurled by the catapults on to the Macedonians. Diodorus gives us a graphic description of a form of vesicant attack. He writes:—

> "Another wonderful invention they found out against the Macedonians, whereby they grievously plagued the chiefest of their enemies, which was this: they filled their iron and brazen shields with sand, and heated them in the fire till the sand was scorching hot, which by an engine they threw upon them that were chiefly engaged, whereby they were cruelly tormented; for, the sand getting within their breast-plates and coats of mail, and grievously scorching their flesh, no remedy could be applied for the cure of the malady; so that (though they made most bitter complaints, as men upon the rack) yet there were none who were able to help them, insomuch that they grew mad by the extremity of the torture and died in the height of inexpressible torments." (2).

(1) "Ibid" ii. XIX.
(2) *Diodorus* XVII. IV.

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Their protective devices were equally remarkable : " They contrived wheels with many spokes, which, being whirled about by an engine, shattered in pieces some of the darts and arrows, and turned off others, and broke the force of the rest." (1). They made great sacks, or cushions, out of hides, stuffed them with hay and lowered them from the walls to break the force of the rams. They made hooked tridents with which they wrenched away the shields of the attackers and fastened sharp hooks to long poles wherewith they cut the cords of the enemy's engines. " They plucked , . . men in armour off the ramparts with iron instruments called crows—shaped like men's hands—and caught others in whirling fishing nets."

We see here the ideas of many of our modern devices, wire entanglements, bursters, shock-absorbers, flame projectors, gas, toxic smoke and vesicant chemicals, and so well were they used, that Alexander saw that to take the city he must gain command of the sea.

4. THE THIRD PHASE OF THE SIEGE OF TYRE.

The mole was rebuilt and widened, so that more towers could be built on it, and, whilst this work was in progress, Alexander went to Sidon " to collect there all the triremes he could ; since it was evident that the successful conclusion of the siege would be much more difficult to attain, so long as the Tyrians retained the superiority at sea." (2).

His efforts were eminently successful. At Sidon he obtained 8 Phoenician ships and 24 from Rhodes, Mallus, Soli, Lycia and Macedonia. Then the kings of Cyprus, hearing of Darius's defeat at Issus, sailed into Sidon with 120 warships. This placed at Alexander's disposal a magnificent fleet of 224 vessels. On these he embarked his Shield Bearing Guards and sailed for Tyre.

He divided the fleet into two wings, the Cyprians on the right, under his own command, and the Phoenician ships on the left under Craterus.

At first the Tyrians resolved to fight, but when he approached them, " they were surprised to see that he was sailing against them with his fleet in due order," and so thought it wiser not to put to sea. Alexander, thereupon, determined to blockade the two harbours. The Cyprian ships, under their admiral Andromachus, were drawn up outside the Sidonian harbour and the Phoenicians outside the Egyptian harbour.

The reduction of Tyre was now but a matter of time, for, if the assault from the mole proved unsuccessful, starvation must accomplish this work.

(1) *Ibid* XVII iv.

(2) *Arrian* ii. XIX.

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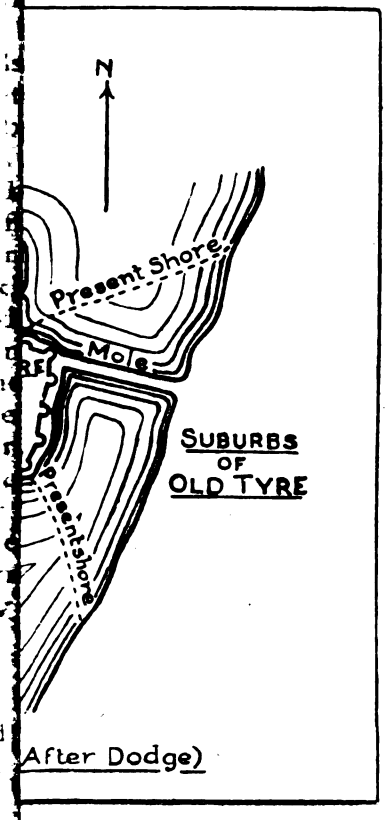

After Dodge)

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5. The Fourth Phase of the Siege of Tyre.

Alexander was not, however, going to wait for starvation to reduce the city. Time, he knew, was the controlling factor, and, if he delayed to take Tyre, Darius might be on him before he could conquer Egypt and gain complete control of the sea and so, if necessary, dispense with his land communications. He constructed, therefore, a number of floating batteries upon which he mounted his rams so as to attack the walls on the flanks of the mole which were "one hundred and fifty feet high, with a breadth in proportion." These walls were protected by large stones sunk in the sea which prevented the floating batteries coming within range. "These stones Alexander determined to drag out of the sea; but this was a work accomplished with great difficulty, since it was performed from ships and not from the firm earth."

To hinder this work, the Tyrians covered a number of their triremes with mail armour and attacked the moorings of Alexander's vessels. Alexander met this manœuvre by placing armoured ships in front of his dredgers. The Tyrians then sent down divers to cut the cables, thereupon Alexander had the cables replaced by chains.

"The Tyrians being now reduced to great straits on all sides, resolved to make an attack on the Cyprian ships, which were moored opposite the harbour turned towards Sidon. For a long time they spread sails across the mouth of the harbour, in order that the manning of the triremes might not be discernible." (1). Under cover of this "screening" they fell upon the Cyprians and drove them back, but Alexander came to their rescue and the Tyrians put back to port.

The new mole was now finished and the great engines erected on it, when it was found that the walls were built on rock and that the work of destruction would be extremely slow. Alexander now determined to force the harbours. This was successfully accomplished, the Egyptian and Sidonian harbours being entered by the Phoenician and Cyprian vessels. Ladders were thrown against the walls, from which the Tyrians were driven by showers of darts and arrows.

At length after a siege of seven months, (2) the city was taken and 8000 Tyrians slaughtered, 2000 later on were executed, and 30,000 sold into slavery. Apollo had proved a false ally and, when Alexander entered his temple, he caused the golden chains to be struck from his limbs and renamed the god Apollo Philaxandrus, that is, the lover of Alexander. (3)

(1) *Ibid* ii, XXI.

(2) Seventeen years after this date, it took Antigonus fifteen months to capture Tyre from Ptolemy. See *Diodorus* XIX. 61.

(3) See *Diodorus* XVII. IV.

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Thus ended this memorable siege, in which every type of device that the ingenuity of the human brain could think out was used in attack and defence. Yet in the end, the energy of a single man, one who scorned defeat, triumphs over all material difficulties and, to-day, as an everlasting memorial to his energy, the sea, having long ago washed the sand against the mole, has changed Tyre from an island into a peninsula.

6. THE STORMING OF THE MOUNTAIN STRONGHOLDS.

The storming of the mountain fortresses, which I will now very briefly examine, constitute examples of leadership rather than of generalship. Their chief interest lies in the difficulties they presented and the energy and cunning which was shown by Alexander in overcoming them.

After the rising of the Sogdianians had been suppressed, the whole of their country was reduced to submission except for a few mountain strongholds which were considered impregnable. One of these, known as the Sogdian rock, or rock of Arimazes, was victualed for a long siege by Oxyartes, a Bactrian chieftain.

This stronghold was apparently built on a ledge or flat topped spur, jutting out of the mountain side. When Alexander summoned the barbarians to surrender, they jeered at him saying that to capture the fortress he would have to send "winged soldiers." This at once suggested to him an idea. To assault the rock would prove most costly, to starve its garrison into surrender would take months, why not, therefore, deliver a moral attack on his enemy. He took them at their word, and, choosing the most precipitous side of the mountain, he selected 300 men who were to climb the face of the rock by driving iron pegs into it and by attaching to these ropes of flax.

This was done, and, out of the three hundred climbers, two hundred and seventy reached the top. Then he sent a herald to the barbarians saying, as he pointed upwards, "there are my winged soldiers." This resulted in an immediate surrender.

The interesting point to note is the rapidity with which Alexander turns conditions to his advantage. In this case, the decisive point was the superstitious nature of his enemy and he at once attacks it, forcing the surrender of an all but impregnable position at the loss of thirty men. This he was able to do only because he valued conditions rightly.

The last stronghold reduced in the neighbourhood of the Oxus was the rock of Chorienes. It rose from a deep ravine, and was, according to Arrian, some seven miles in circumference and could only be approached by a narrow pathway cut in the rock.

Alexander forced its surrender as follows. First he had a number of ladders made to enable his men to descend into the ravine. Next

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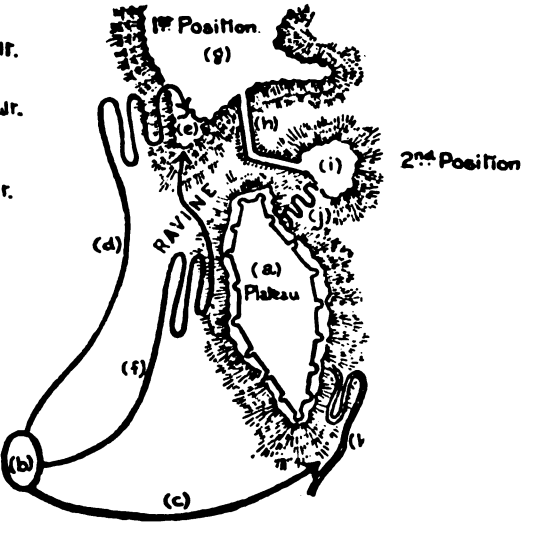
he built up an extensive crib-work bridge across the ravine so as to reach a level with the top of the rock. When once this work had progressed sufficiently far to enable his missile throwing engines to be brought into play, Chorienes surrendered to him and was rewarded for doing so by being made governor of the surrounding country.

When Alexander marched through the mountains north of the Cabul river, the inhabitants deserted their towns and villages and sought refuge on the rock of Aornus. It has been identified as mount Mahabunn on the right bank of the Indus and some sixty miles north of Attock. On its summit, which was flat, was an extensive area of arable ground and a plentiful supply of water. Tradition related that, when Heracles invaded India, he had failed to take Aornus, this in itself was sufficient reason for Alexander to do so; but take it he must if only to maintain his prestige, for it was his prestige which secured his far-flung line of communications.

(a) Plateau of Aornus.
(b) Alexander's Camp
(c) Alexander's First Assault.
(d) Ptolemy's Approach.
(e) Ptolemy's Stockade.
(f) Alexander's Second Assault.
(g) First Position.
(h) Mound.
(i) Second Position.
(j) Alexander's Final Assault.
(k) Main Road.



ROCK OF AORNUS (After Dodge).

The attack on this stronghold is interesting and it may be followed by means of the diagram (1).

Having selected a lightly equipped force, he placed Ptolemy, son of Lagus, in command of it and sent him to seize the mountain ridge abutting on the rock, but separated from it by a ravine. Once in occupation, Ptolemy was to signal to Alexander who, whilst Ptolemy attacked the rock from the north, would attack it on its southern flank, "so that the Indians, being assailed from both sides at once, might be in perplexity what course to pursue." (2) This attack

(1) Taken from Col. Dodge's "*Alexander*," Vol. II. p. 529.
(2) *Arrian* IV. XXIX.

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failed. The second assault, which was delivered against the western flank of the rock, was equally unsuccessful.

Alexander now changed his plan. First, he united his forces with those of Ptolemy. Next, he constructed a mound from the mountainside to a hill which was on a level with Aornus. The Indians now took alarm and suggested a truce, over the terms of which they argued, as their plan was to gain sufficient time to permit them to secretly leave the rock and seek refuge in the mountains. Alexander, discovering this ruse, at once took advantage of it. He gave the enemy time to begin their retirement, then, from the small hill, he assaulted the plateau and fell upon his enemy when he least expected it. "Thus the rock which had been inexpugnable to Heracles was occupied by Alexander."

7. ALEXANDER AVOIDS SIEGES BY MEANS OF THE MORAL ATTACK.

Since the days of Alexander, the art of siege warfare has changed almost out of recognition, but unless we recognise the difficulties which these sieges entailed, we shall fail to get a true picture of the art of war during this early period. Under the Romans, sieges were frequent, yet not much was added to the art as established by Philip and Alexander. During the Middle Ages, the art, in Western Europe is almost entirely lost, and towns and fortresses are forced to capitulate through starvation or by treachery, and seldom by force of arms Not, until after the Renaissance, does the ancient art of siege warfare re-appear.

To Alexander, sieges were necessary evils, and to limit their number he used terror as a means of overcoming walls. When a city refused submission he never passed it by, and for a definite moral reason—loss of prestige. To paralyse the initiative of a superstitious world, ruled by deities conceived as superior human beings, Alexander always aimed at the super-human—he knocked the gods off their pedestals. There can be little doubt that, in his days, the world in general looked upon him as a god or a heaven-born hero, consequently he was compelled, not only for the sake of vanity but for that of prestige, to overcome all difficulties, and, as each fell victim to his will, his sway over his immense empire, became more sure.

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NOTES ON THE ELECTRICAL AND MECHANICAL COURSE.

By LIEUTENANT J. T. GODFREY, R.E.

FROM the number of enquiries he has received on the subject, the writer thinks that a few remarks on the scope and possibilities of the E. and M. course may be of use to others intending to apply for it; and he has included some hints from his own experience for what they are worth, as to how the course may be tackled.

There are four aspects which invite attention :—

1. The type of work.
2. The mode of life.
3. Exercise and social possibilities.
4. Expenses.

Firstly, the type of work. On reporting at the War Office, an officer is allotted a preliminary programme usually extending over about three months. The authorities are very considerate of the individual's convenience, as far as that is possible; and if an early interview can be arranged, say, a month or two before the course starts, even the preliminary programme could probably be adjusted with that end in view.

The course is divided into a number of periods of different lengths, from one to eighteen weeks, and certain subjects to be learnt (*e.g.*, Pumping Machinery) are allotted to each period. As long as the subjects and periods are not radically altered, there is a fairly large choice of individual firms for the various subjects. This choice may be limited by the number of officers already with a particular firm, since usually there are only two vacancies at a time at any one firm.

The types of firms may be roughly classified into the large, the medium, and the small.

Type 1. The large are those which have a number of branches or departments, at which different subjects may be studied all under the one firm, *e.g.*, the General Electric Company, the British Thomson Houston.

Type 2. The medium are those which have a considerable works devoted only to one subject, say, oil engines, but which may possibly extend to two.

Type 3. The small are one-subject firms with less expensive machinery and appliances, or are the geographically distinct branches of a major firm.

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A few pros and cons that occur to the writer are tabulated below:—

	Advantages.	Disadvantages.
Type 1.	Large range of subjects. The latest and best methods are in practice. Six to eight months may be spent in one place, so that frequent moves are avoided. Often there is an apprentices' Club with facilities for games.	A great many types of work are in hand which are well outside the range of service requirements, even in the future. Often a very rigid administration ! A lot of time can be spent on matters that are of no practical value to an R.E. Officer, but which are very interesting.
Type 2.	In general, the smaller the firm, the better the personal attention to the learner's requirements.	Usually only a short visit, but there is here the advantage of change to keep up interest.
Type 3.	In this type the conditions approach more nearly to those found in the Service and there is better scope for practical work.	No messing amenities for lunch, etc., and as in 2 above.

Throughout the course it is very helpful (1) to know what is *not* required to be learnt of a particular subject, (2) to combine practice and theory; *i.e.*, to look up the subject in text books at the time; and (3) to keep a record of the practical side, workshop tips, and methods of testing and repair. The details of manufacture need not be investigated *deeply*, though works management, modes of supervision, checking and testing are of great value, especially the last; and a good proportion of the officer's time should be spent in the testing departments. Wherever possible, he should apply to the works manager to be sent on installation work, after he has gained a general insight into shop practice.

No period is specially allotted to the study of machine tools, yet they exist in every factory, and the officer should allow himself so much time in every works to learn about them. The general-purpose machines are far more useful than the specialised repetition machines, for military workshops.

The Power Station.—This is a subject to which a considerable time is given. In the writer's opinion it is probably better not

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to go to the largest, since the occasions on which an R.E. Officer will have charge of more than 5,000 K.W. will be rare, and the more usual run is 500 K.W., if that. At the same time it must be admitted that the larger the station the more organised the management usually is. Plenty of time should be allowed for A.C. work, especially distribution, H.T. and L.T., transformers, motors and switchgear: this implies attention to sub-stations and their equipment.

A fact to be remembered is that in military life the reciprocating steam engine is far more common than the turbine, though knowledge of the turbine is essential. In this connection, it is very necessary to know what is the best *equipment* for any given turbine or boiler: for instance, the condensers, pumps, valves, circulating system, and especially the governor gear, are as important as the machine itself, and in the case of the boiler, the feed-pumps, steam mains, stop-valves, safety valves, flue dampers, feed regulators, mechanical stokers, fans, steam traps, and so on, often require more attention than the actual boiler.

The period with the consulting engineers was in the writer's case the most profitable and interesting part of the course: after the shortest of preliminaries, the officer works simply as an engineer of the firm, and gains very valuable experience on large work that is actually in hand.

It is very easy throughout the course to specialise almost unconsciously either on the mechanical or the electrical side: but from the R.E. point of view this very nearly amounts to an offence under Section 40 of the Army Act.

Mode of Life.—On arrival at the works, which should take place early in the day, the first requirement is to ask the manager if he has a list of lodgings, which is usually the case; and the first day can be spent settling in. Hotels are generally expensive, but are often useful till a good lodging has been found. N.B.—Enquire if there is a bath, as baths are sometimes non-existent.

The official works hours are generally 8.30 to 1, 2 to 5.30 or 6.0 in the winter, and half-an-hour earlier in the summer. In the larger firms " clocking-in " is the usual custom.

There are two points in connection with lodgings: (1) One's comfort depends entirely on the qualities of the landlady. (2) Lunch is often provided at the works, with the supervisory staff; and it is as well to find this out from the manager, and arrange accordingly.

Two pairs of overalls are necessary; and in the matter of getting dirt off one's hands, *always* rub in slightly moist soap and get it well under the nails, *before* starting work. If very dirty, wash them with oil first, and then with soft soap and sawdust, or one of the many patent gritty soaps.

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Exercise and Social Possibilities.—Exercise is difficult to get during the week, and after standing up for eight-and-a-half hours one is distinctly foot-weary to start with. During the winter it is next to impossible, except at week-ends, and unless there is a local club for rugger, hockey, or soccer. To reach places where exercise may be obtained some means of transport is very desirable, even the humble bicycle being better than nothing. In the summer conditions improve, and the officer who has a car can always get away for tennis, golf, or fishing and shooting if he makes the necessary arrangements.

Leave is officially six weeks in the year, to be taken at any time that is convenient between subjects.

As regards social life, an officer should either ask to go to a region where he already has friends, or should get from his friends and relations an introduction to a local resident; given that start, the rest follows. The difficulty may often be in finding time to get away, and not in a lack of acquaintances.

If the firm is a large one, the apprentices, who are often Cambridge men, will probably have a cricket club; and if the worst comes to the worst, the fortnight with the Manchester Steam Users' Association, spent on boiler inspection, is equivalent to a fortnight's climbing in a tropical climate.

Expenses are very much in the officer's own hands; he may live very cheaply, or as expensively as his bankers will permit. Full pay and allowances are drawn.

To conclude with a few general remarks. The choice on the whole lies between a prolonged stay in one of the large towns, London, Manchester, Birmingham, or possibly Glasgow, and a series of fairly frequent moves among the smaller towns, or a mixture of the two. Detailed information about the individual firms can be obtained from a list in the War Office when officers report. It must be remembered that these notes have been written from the experience of a single officer, who cannot know more than a limited number of firms, so that the generalisations expressed may be quite misleading for a particular firm outside his knowledge.

Uniform need not be taken, but the flannel trouser is a very present help; and unless the more stationary type of life is preferred, it is best to travel light.

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HISTORY OF THE 12th COMPANY, ROYAL ENGINEERS.
(Continued).

By LIEUT. M. R. CALDWELL, R.E.

CHAPTER V.

THE SOMME (*See Map* 6).

On the afternoon of the 3rd August, 1916, the Company detrained at Candas-Fienvillers, and, marching *via* Beauval and Arquèves, arrived at billets on the Englebelmer-Martinsart road, the transport and rear Headquarters remaining at Acheux.

The 18th Infantry Brigade had meanwhile taken over a sector from the River Ancre to the southern edge of Beaumont-Hamel. The trenches here, in contrast to those in the Ypres Salient, were deep, wide and dry, with mined dug-outs, and the ground was very chalky.

Work in the New Sector.—Until the 25th the Company was engaged in the construction of mined dug-outs, and the lay out and construction of a new front and support line with strong points, which were afterwards used as assembly trenches by the Naval Division in their attack in November. This latter work, which was mainly carried out by Nos. 2 and 4 Sections (Lieuts. Regnard and Johnson), was of no easy character, having to be carried out close to a vigilant enemy and on an exposed ridge where the hard chalk made silent working an impossibility. The parties were, consequently, night after night subjected to a heavy and accurate trench mortar bombardment which caused heavy casualties and severely shook the men, and would, but for the coolness and judgment of the officers in charge, have had very serious effects.

Whilst in this sector the men were subjected to gas shell bombardments for the first time, and underwent several unpleasant experiences in the neighbourhood of Mesnil and Hamel, the chief centres of this activity.

On August 26th the company were relieved, and, marching *via* Amplier and Gezaincourt, arrived on the 29th at Vignacourt, where they remained for a week for drill and training. Leaving on the 6th September, they marched *via* Rannecourt to Sailly-le-Sec, where they arrived the next day. Three days were spent here prior to moving up into the assembly positions for the attack which was about to come off on the intricate network of trenches known as the Quadrilateral.

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Attack on the Quadrilateral.—The assembly positions were reached early on the morning of the 14th, the Company being placed in some disused trenches in front of the Briquetterie, near Montauban. The Division was in the line in front of Guillemont, with the 18th Brigade in reserve, so that, when the attack took place the next day, the Company's work consisted only of road making up into Guillemont.

The attack was only partially successful, the centre of the Division being held up by the Quadrilateral itself, and the 18th Brigade was therefore ordered to carry out a further attack. Accordingly, on the night of the 17th, No. 3 Section taped out an assembly position across the front, and the 1st Battalion West Yorkshire Regiment was led into position.

The attack on the morning of the 18th was entirely successful, and the Quadrilateral was taken, together with nearly 1000 prisoners. As soon as the objectives were reached, Nos. 1 and 2 Sections carried out the construction of strong points on the flanks with but little interference from the enemy, one man only being wounded.

That same day the 6th Division was relieved, and the Company marched back to Meaulté for two days' rest.

Attack on Les Bœufs and Morval.—On September 21st, Nos. 2 and 3 Sections moved up by lorry to the north of Guillemont to prepare a battle Headquarters for the 18th Brigade for an attack on Les Bœufs and Morval, the remainder of the Company bivouacking behind Trones Wood.

During the next three days Brigade Headquarters and assembly trenches were prepared, and, on the night of the 24th, Nos. 3 and 4 Sections (Lieuts. Langley and Johnson), took up positions in the assembly trenches North East of Ginchy, Nos. 1 and 2, under Lieut. Regnard, being held in reserve.

On the morning of the 25th, the 6th Division, with the 16th Brigade on the left and the 18th on the right, attacked in conjunction with the Guards who were on their left. The operation was a great success, all the objectives including the villages of Les Bœufs and Morval, together with several thousand prisoners being taken with but little loss, and an advance of about two miles was achieved.

The sappers, with a carrying party of 25 infantry to each section, advanced with the Rear Lines. No. 4 Section came through the enemy barrage successfully, but No. 3 were less fortunate, losing three men killed, including Sergt. Pellowe, the Section sergeant, and seven wounded, besides about half the carrying party.

On reaching the final objective, No. 3 Section, working on the extreme left with the Guards, and No. 4, with the 16th Brigade, constructed two strong points, each consisting of a machine gun post with supporting rifle pits connected up to the general line, and

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wired them in on the flanks with French concertina wire strengthened with barbed wire and screw pickets.

Infantry patrols which were now sent out met with little or no resistance and the enemy did not greatly further interfere, so that by nightfall the work was finished and the sections were withdrawn to their bivouacs at Trones Wood. For the gallantry displayed during this operation, Lieut. Langley was awarded the Military Cross, Sergt. Caulfield, of No. 3 Section, the Military Medal, and Sergt. Clark the Distinguished Conduct Medal.

On that and the following evenings, Nos. 1 and 2 Sections under Lieut. Regnard went up to continue further consolidation, and on the night of the 27th the whole Company turned out and erected two belts of wire along the front and support lines, each over 1000 yards in length.

On September 28th, the Company marched back to the Briquetterie at Montauban and thence to Méricourt, stopping a night at Meaulté and Ville sur Ancre on the way. Here five days were spent, resting and refitting after the strenuous days just gone through.

On October 7th, the Company marched up to the Citadel, moving into dug-outs in rear of Longueval the next day. The 18th Infantry Brigade had taken over a part of the line east of Guedecourt, and, during the next three days, the Company was employed on wiring and constructing dug-outs in this Sector.

Attack near Le Transloy.—At 1400 hours on the 12th, the 18th Brigade carried out a small attack on the line north of Le Transloy, but were not very successful, making only very little headway against a determined resistance. No. 1 Section, under the command of 2nd Lieut. G. W. Jack, accompanied the leading waves, and, after capturing several prisoners, assisted in the defence and consolidation of the little ground wrested from the enemy. 2nd Lieut. Jack set a fine example of coolness and courage under very trying circumstances, and was subsequently awarded the Military Cross.

At 0535 hours on the 15th, another attack on the same ground, made by the 2nd Battalion Durham Light Infantry and 11th Battalion Essex Regiment on the left with the Sherwood Foresters on the right, met with but little more success, being held up by machine guns which had been insufficiently dealt with by the artillery. Nos. 2 and 3 Sections (Lieuts. Horne and Langley), came up at dusk to carry out consolidation, and did useful work in forming bombing posts and blocking communication trenches leading to the enemy's lines. Lieut. Horne was unfortunately wounded during the operation.

On the 19th the 6th Division was relieved and that day the Company marched back *via* the Citadel to Méricourt. Whilst here Captain A. Campbell, D.S.O., who had commanded the Company since July, 1915, left to take over the duties of Staff Officer to the Chief Engineer XIV Corps.

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Move to Allery.—On October 22nd the dismounted personnel proceeded by train to Allery, the transport moving by march route. Here the Company spent nearly a week, resting, training and refitting.

Move to Bethune Area.—On the 29th the Company moved by rail to Choques, and marched thence to Marles-les-Mines, where they carried out further training until November 5th.

On the 6th the Company was unexpectedly ordered to Mazingarbe, where they relieved the 103rd, 104th and 129th Field Companies of the 24th Division, who were employed in the construction of deep dug-outs. No. 2 Section, under 2nd Lieut. Newland, proceeded to Maroc. The work on the deep dug-outs was continued for three weeks, the men working in continuous shifts of six hours and having an hour's march from and to billets.

Whilst here Capt. A. M. Jackson, M.C., returned to assume command of the Company, and Lieut. Regnard received his captaincy and became second in command.

On November 29th the Company rejoined the 18th Brigade, Headquarters moving to Beuvry, with two forward sections to Cambrin.

The ground in this sector was flat and low lying, somewhat similas to that in the Ypres salient, and consequently great difficulty war experienced in the drainage and upkeep of the trenches. The pressure of this work was often very great, so that at one time nearly all the available men were employed on two main communication trenches and the front line posts, little other work in consequence being done.

A few machine gun and trench mortar emplacements were also constructed, and at Beuvry the rear sections were employed on hutting for the reserve troops.

The Company carried on this work until February, 1917, the Brigade carrying out several raids during the period, for a few of which a German portable searchlight was taken forward by the Company, and used successfully to give a signal for the return of the raiding party.

During this period the recreational facilities were very good, and the close proximity of Bethune, the Divisional Concert Parties there, and the Divisional Cinema at Beuvry, were much appreciated by all ranks.

On February 13th the Company moved back to Garbecque on the Aire-Bethune canal, where an extensive training programme was organized, the dismounted men being practised in drill, musketry and pontooning on the canal, and the mounted section in riding and driving drill, while the afternoons were given over to football, obstacle races and cross country runs.

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Loos Area (*See Map 7*).—On the 25th the Company moved to Gonnehem for a further two days' training prior to marching to Bethune on the 28th and on to Les Brébis the next day. Here Headquarters and the Reserve Section were established in the School, while the horses were accommodated in excellent stables a little further up the street. Three sections were sent forward to Loos where they were quartered in cellars, the officers living in a dug-out near the R.E. dump in the centre of the village.

The new sector largely consisted of ground over which the battle of Loos had been fought 17 months before, and was covered with a maze of trenches, many of them disused relics of the earlier fighting.

The Crassier and Loos village were prominent features in the locality, the former being useful for observation purposes, although it formed a barrier to communication with the line to the right. The village was garrisoned by a large number of troops and was a centre of great activity both by day and night, forming a rendezvous for the Brigade working and carrying parties, and was full of dumps of rations, ammunition, bombs and R.E. material.

On their arrival the Company found the line in a deplorable condition, the trenches being unrevetted and the chalk sides having fallen in wholesale after the hard frosts in February. Consequently, one of the forward sections was at first almost entirely used for supervising the infantry working parties engaged in the improvement and reconstruction of the trenches. However, by the middle of April a vast improvement was noticeable and from then onwards little difficulty was experienced in keeping the more important trenches in first class order, thus enabling work to be concentrated on other improvements necessary to the defences.

One interesting piece of work was the construction of a bombing and observation post on a small mound known as the "Hump," which was only 25 yards from the German line. A bank connected the Hump to the front line, and was used to give a covered approach, whilst the post itself was hidden by means of careful siting and camouflage.

During the latter half of March, the remainder of the sappers were concentrated on building-in wooden boxes under the parapet of the front line as emplacements for gas cylinders to be used in an attack in April.

In May, the reconstruction of the pipe line from "Fosse 7" was undertaken and the pipe line carried forward as far as the Reserve Line. A new pumping station was also erected in Loos and a 4" main laid along the Hulluch Road for use during the operations in August.

The men were also constantly engaged in the construction of mined dug-outs and trench mortar emplacements, as well as the upkeep of the cellars in Loos, which required constant attention

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owing to the frequent bombardments to which the village was subjected.

In April, detachments of 25 men per battalion were attached to the Company, and were invaluable for supplying the unskilled labour necessary for the economical completion of these works.

As this sector was on the fringe of the Spring offensive at Arras, raids and counter-raids became very frequent. Artillery and trench mortar activity consequently increased and Loos became more and more devastated, the troops being gradually withdrawn from the village as the cellars and dug-outs were knocked in.

Major Jackson killed.—During this period casualties were fairly frequent, the greatest loss occurring when Major Jackson was mortally wounded while going round the line on April 27th. He had joined the Company on Mobilization in 1914, and, apart from a short absence in 1916, had served with it continuously till the time of his death, which robbed both officers and men of a fine leader and a friend in adversity.

Lieut. Newland was also wounded on May 25th.

On June 25th another calamity occurred when a cellar containing some of the attached infantry was blown in, burying six men. One of them was recovered alive, though badly gassed, but while the rescue parties were still at work another shell hit and detonated a bomb store in an adjoining house, both buildings being totally demolished. The casualties were serious, 1 N.C.O. and 2 sappers of the Company being wounded, and of the attached infantry 6 were killed and 5 wounded. After this the cellars in Loos were finally evacuated, and the forward sections took up their abode in some dug-outs in a camouflaged trench behind the Lens road.

Captain A. M. Williamson now assumed command and Lieut. G. W. Jack received his captaincy.

On July 14th the Company was withdrawn to Labourse where they were employed for a week in laying on water, putting down concrete horse standings, and erecting huts at the camps and water points.

A long rest.—On the 22nd, the Division being relieved, the Company marched back to Guestreville, where a month was spent, the mornings being occupied with lectures and training in drill, musketry and fieldworks, while the evenings were given over to sports.

On August 9th the Chief Engineer 1st Army inspected the Company. On the same day a highly successful Brigade sports and boxing meeting was held, in which the Company tug of war team, coached by C.S.M. Rouse, reached the final, while Sergt. Dowe distinguished himself at boxing.

Advantage was also taken of the lengthy rest to renovate equipment and wagons, and when the three Field Companies were inspected

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by the G.O.C. 6th Division on August 22nd, the parade was quite up to peace time standards.

Return to Les Brébis.—On August 23rd the Division returned to the line, the Company taking over from the 8th Field Company R.C.E. Headquarters and Reserve billets were again at Les Brébis, and the forward sections found accommodation in deep dugouts at Harts Corner.

The work, for the first month, consisted of consolidating the newly won position on Hill 70, and, after the division side-stepped to the South on September 21st, another month was spent in preparing for future operations in the Cité St. Auguste area. During nearly the whole period an average of 400 men were employed nightly as working and carrying parties, while the sappers who were not required for their supervision were employed on shelters and machine gun emplacements in the front line, and strengthening and fitting out cellars for use as Advanced Dressing Stations, etc.

The sector was subjected to fairly heavy fire over the whole period, and at first, until the trenches had been dug down to the normal depth, casualties were heavy. Lieut. O. C. H. Osmaston, M.C., was killed in Netley Trench, and Sergt. Clarke, his section sergeant, and two sappers were wounded, on August 26th, while on the 30th, Lieut. Obbard was wounded. Afterwards, however, casualties fell off considerably, and in spite of several enemy raids, preceded by violent bombardments, no untoward events occurred.

Move of the 6th Division.—On October 23rd the Division was withdrawn from the line and the Company marched to Noeux-les-Mines, moving thence by train to Lillers, and marching again to Esquedecques, the transport moving by road. Here they spent four days, refitting, bathing at Lillers, and resting prior to moving South to join the IIIrd Army.

On October 29th the Company marched to Magnicourt-en-Compté, and the next day to Grand Rullecourt. They were then split up, Nos. 1 and 2 sections under 2nd Lieut. Newland remaining at Rullecourt, while on November 1st, Headquarters with Nos. 3 and 4 Sections entrained at Saulty for Fins, the transport having left the day previously by march route.

Rumours of a coming battle had been rife for some time, and during the next three weeks there was great activity, conducted at the same time with much secrecy and concealment. The Sections at Fins, who moved to Queens Cross on November 17th, were occupied in erecting shelters and camouflage, while Nos. 1 and 2 at Grand Rullecourt were carrying out manoeuvres in co-operation with infantry and tanks.

Battle of Cambrai (*See Map* 8).—On the morning of the 20th, the surprise attack was launched, the 6th Division advancing on the line Villers Plouich—Beaucamps, the 16th Brigade on the right next to

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the 20th Division, while the 71st Brigade were on the left next to the 51st Division. All went well on the Divisional front, the Hindenburg Line and the village of Ribecourt being captured early, and the 18th Brigade then advanced through the 71st and captured Premy Chapel Ridge. A defensive flank had then to be thrown back on the left towards Flesquières where the 51st Division had been held up.

Nos. 2 and 4 Sections (Lieuts. Newland and Veitch) were attached to the 18th Brigade and moved forward with them at 0800 hours, each having two sections attached Infantry and five pack animals loaded with wire and sandbags. No. 3 (Lieut. Langley) was in Brigade Reserve and No. 1 (Lieut. Vachell) was in Divisional Reserve at Queens Cross.

Nos. 2 and 4 began work on strong points on the defensive flank before noon, and No. 4, on the right, completed its task without incident. No. 2, however, were less fortunate for they were working on an exposed ridge in full view of the enemy in Flesquières and the Beetroot Factory, and consequently soon came under heavy machine gun fire which caused several casualties, among them Lieut. Newland, who was mortally wounded. Owing to this fire and to the loss of the Section Officer, the work was greatly delayed, and the Section was relieved at dusk by No. 3 who completed the task.

Meanwhile, as soon as the advance had got under way, Headquarters and No. 3 Section advanced along the Beaucamps—Ribecourt road, sending forward parties to reconnoitre the German Dumps at Ribecourt Station and on the Grand Ravin rivulet. These Dumps were, however, burning, and not much could be salved.

The road was cleared by the 11th Battalion Leicestershire Regiment (Pioneers), and at midday Lieut. Hall with three pontoon wagons loaded with sandbags, wire and pickets, and with Nos. 2 and 3 Sections' Tool Carts, arrived in Ribecourt, this being the first transport to arrive in the village.

The casualties during the day's fighting had been one officer and one other rank killed, and of the attached Infantry three other ranks killed and three wounded.

Advance held up.—The advance had now been checked, and unfortunately the morning's high hopes had not been realised, and the longed for " break through " had not occurred. The next nine days were therefore spent in consolidating and fortifying the newly won positions. On the 21st another strong point was built on the Premy Chapel Ridge and during the following days a large amount of work was carried out on wiring, trenches and shelters in the Cantaing—Premy Chapel area. During the nights of 27th, 28th and 29th November, first Nos. 2 and 3 Sections and subsequently the whole Company were employed on wiring, the wire and pickets being brought up to the centre of Cantaing Village in wagons and

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thence carried up to the wiring parties. In spite of the brilliant moonlight, there was little interference from the enemy, and in three nights two belts of wire, each six yards wide and about a mile long, were erected.

German Counter Attacks.—In the early morning of November 30th, the enemy launched heavy counter attacks from the North and East, their object being to pinch off the salient which the advanced troops were holding. The attack on the North failed, but that from the East penetrated our line, and by 9 a.m. Gouzeaucourt was in German hands. The situation at Ribecourt was critical, and the transport at Beaucamps had to beat a hasty retreat under machine gun fire. The Company was at once ordered to " Unseen " Trench off " Argyle Road," and kits were hastily packed and despatched in a commandeered lorry to Metz. The two Tool Carts were manhandled up the Trescault Road until met by their teams near the Hindenburg Line. The Company moved off and found that all transport moving out of Ribecourt was blocked owing to the bridges over the Hindenburg Line having been broken. These were soon repaired by Nos. 1 and 4 Sections, after which the Company proceeded to " Ridge Trench," in the Hindenburg Line, overlooking Couillet Wood, where they came under the orders of Lieut. Colonel Rosher commanding the 14th Battalion Durham Light Infantry.

The remainder of this day and the next were spent here, as a further German attack was expected, and as the trench ran at right angles to the probable line of advance, both parapets had to be manned.

The attack did not develop, however, and the Company returned to their old billets in Ribecourt at 1 a.m. on the 2nd, and going out again that night wired around Cantaing, Nos. 1 and 4 strengthening the front line, and Nos. 2 and 3 the support line.

During the previous day the Germans had attacked from La Folie Wood, but were met by the wire previously erected by the Company and were repulsed.

On the morning of the 3rd December the enemy captured the bridgehead at Marcoing, and in the afternoon the Company was ordered to relieve two companies of the 2nd Battalion Durham Light Infantry in the Hindenburg Support Line. At 8.30 p.m. they relieved the two Outpost Companies of this Battalion, but were moved again in the early morning, and at 5.30 a.m. settled down in a reserve position, after a very tiring night of marching, uncertainty of the situation, and numerous orders and counter-orders. They remained here till 7 p.m. when the men moved off to wire along the new outpost line on the Premy Chapel Ridge. On the 5th they wired the support line, and on this and the previous night put up about two miles of wire in spite of the ground being frozen hard. They

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then returned to new billets in the Hindenburg Line off the Trescault Road.

On the 6th two derelict tanks in No Man's Land, which were being occupied by enemy posts and snipers, were destroyed with 280 lbs. of guncotton apiece.

For the next four days work was concentrated on consolidating the new positions which our troops had occupied, and a great deal of work was done every night on the new front line, which was laid out to connect the defences on Premy Chapel Ridge with Flesquières.

6th Division relieved.—On the 11th, having been relieved by the 82nd Company R.E., the Company marched *via* Metz to Etricourt, moving the next day to a rest camp in Hendecourt. It was now hoped that, after the strenuous times just gone through, the men were to have Christmas amidst pleasant surroundings, but it was not to be, for on Christmas Eve they were hurriedly moved to a barren camp in Bapaume to undertake important hutting work.

Louverval Sector.—They remained here until January 19th, 1918, when the work was handed over to the 459th Co. R.E. and the next day they moved into the Line again and took over the Louverval Sector the dismounted men marching to Laboquiere and the transport to Beugny.

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PROFESSIONAL NOTES.

REINFORCED CONCRETE ROADS.

The writer has recently had the opportunity of seeing some of the concrete road construction that is being carried out in the County of Surrey, and it is thought that a few notes on the subject may be of general interest.

A. The Kingston Bye Pass Road.

(1) *General Description.*—This new road, approximately 10 miles long, is being constructed by the Surrey County Council in order to relieve Kingston and Surbiton of the through traffic on the London-Portsmouth Road. It runs from Beverley Brook to Esher via Tolworth and Hook.

It is proposed that its ultimate width, exclusive of banking, should be 100 feet and the ground for the purpose has already been fenced off; but the carriage way is only being constructed with a width of 30 feet at present. The fencing is of the concrete post and galvanized wire type that is becoming so common.

The subsoil is a stiff sandy clay. All grading is done at least six months in advance before any further work is undertaken. A bed of clinker is then laid down and well rolled to a depth of about three inches. On top of this comes eight inches of concrete in two layers with steel reinforcement. The exact type of surfacing has not yet been decided on, but it will probably be a thin coating of some bituminous material. The road is given a camber of 1/50.

(2) *Details of Concrete.*—The concrete is in two layers of different composition; the bottom layer being six inches of 4:2:1 concrete, and the top layer two inches of 3:1½:1 concrete. Both the coarse material and the sand are washed, screened, and carefully graded: one inch stones are the largest used in the bottom layer and ¾ inch in the top. The placing of the top layer is begun immediately the bottom layer is in position. The ingredients are mechanically mixed in a batch mixer having a capacity of half a cubic yard. The mixer travels on rails at the side of the road, and an overhead girder extends from it across the road to a support running on a rail on the other side. When mixed the concrete is tipped out into a skip, which travels suspended from the girder and deposits the concrete where required.

Great stress is laid on cutting down the amount of water used to the minimum compatible with ease in handling. The total

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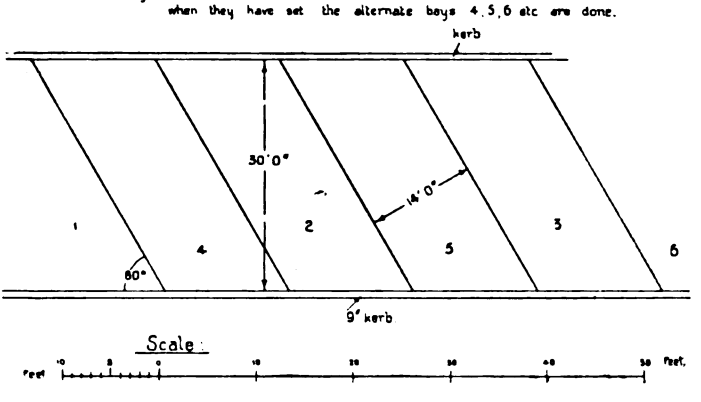
amount is stated to be about 25% by weight of the amount of cement used; the actual amount added to each batch mixed depending, of course, on the atmospheric conditions and the amount of water already present in the stone and sand. It is said sometimes not to be necessary to add any water at all. The hardness of the concrete has proved to be extremely satisfactory.

After being deposited from the skip the concrete is spread and rammed. It is levelled off by means of a wooden beam on edge worked backwards and forwards by two men across the top of the shuttering. The beam is shod with steel.

About 24 hours after the concrete has been placed in position the surface is brushed with stiff brooms to remove all scum and laitance. When this has been done a layer of soil is thrown on top and kept damp if necessary by watering for at least 28 days.

The concrete is laid in alternate bays running right across the road and 14 feet wide, at an angle of 60° to the direction of the road. (See *Fig.* I.) The object of the latter is to transfer the weight of

Fig. 1.—Plan of Road.



vehicles gradually from one slab to the next; each wheel crossing the joint between two slabs separately, and, also, since the wheel has a definite width, its weight is transferred gradually from one slab to the next. It was also suggested that by this method the expansion of the concrete in the direction of the road is to some extent taken up by a shearing action of one slab against the next, but the argument was not at all clear.

It was observed that in some cases difficulty had been experienced in screeding the intervening bays to the exact level of those first laid down, and it is thought that the slight difference in level may cause vehicles to bump at the joint, and subject the road to undue stresses.

(3) *Details of Reinforcement.*—The type of reinforcement used varies in different parts of the road according to the nature of

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the ground. The size of the rods used is determined entirely by practical experience.

The heaviest type is that shown in *Figs.* II. *a*, *b* and *c*. It consists of a double layer reinforcement with shear members. The bottom layer of reinforcement consists of a 9-inch mesh of bars 9/32 inch in diameter laid at right angles to each other. The bars are not interlaced, but are bound where they cross with No. 16 S.W.G. wire.

Fig. 2a. Plan of Part of Reinforcement for Primary Bay.

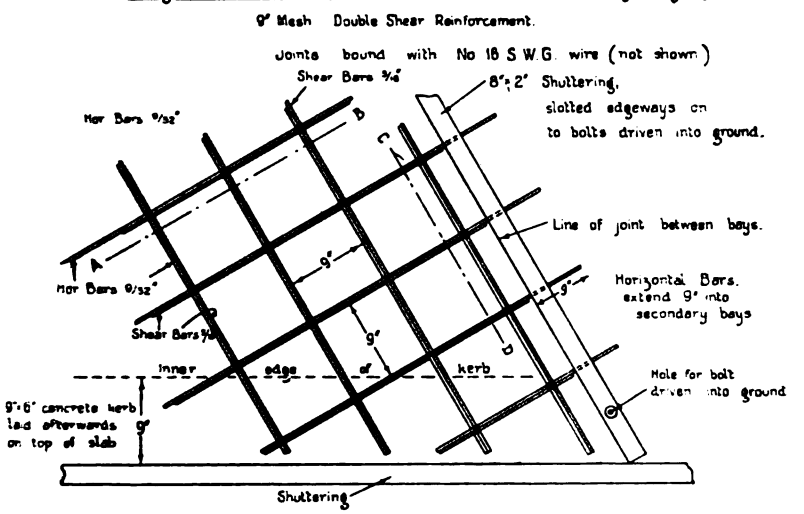

9" Mesh Double Shear Reinforcement.
Joints bound with No 16 S.W.G. wire (not shown)
Shear Bars 9/32"
8"x2" Shuttering, slotted edgeways on to bolts driven into ground.
Hor Bars 9/32"
Line of joint between bays.
Hor Bars 9/32"
Horizontal Bars extend 9" into secondary bays
Shear Bars 9/32"
9"
9"
9"
Inner edge of kerb
Hole for bolt driven into ground
9"x6" concrete kerb laid afterwards on top of slab
9"
Shuttering

Fig. 2b. Section on A-B.

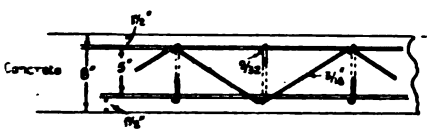
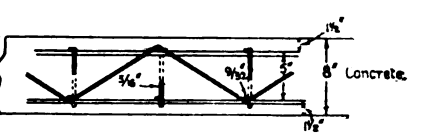


Fig. 2c. Section on C-D.



This reinforcement is placed 1½ inches from the bottom of the concrete. The top layer is exactly similar and is placed 1½ inches from the top of the concrete leaving 5 inches in between the two layers. Here is placed the shear reinforcement consisting of 3/16 inch diameter bars running diagonally from joint to joint of the horizontal reinforcement in both directions.

In places where the subgrade is judged to be stronger, half or all the shear reinforcement is omitted, and ¼-inch bars used, instead of 9/32-inch, in the horizontal reinforcement.

The reinforcement is wired up into mats on the site. It runs continuously through the joints, the horizontal bars sticking out 9 inches on each side of the bars first laid down, and being wired to the reinforcement of the alternate bars when these in turn are concreted.

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The reinforcement is kept in its proper position while the concrete is being poured by passing the horizontal members through holes in the shuttering. The latter consists of 8in. boards slotted edgeways on to bolts driven into the ground. The boards are cut along the lines of holes for the reinforcement into three widths of 1½, 5 and 1½ inches respectively, thus enabling the reinforcement to be easily inserted, and the shuttering to be easily removed when the concrete is set.

(4) Mr. J. H. Walker, M.I.C.E., of the Walker-Weston Co., Ltd., who accompanied the writer, had the following comments to make :—

(*a*) While it is undoubtedly essential to prevent the slabs from getting out of level, since if they do so the road quickly gets broken up by the traffic at the joint, to run the reinforcement through the joint destroys the value of the latter as an expansion joint. To provide a proper expansion joint, and prevent the road from cracking under the influence of temperature changes, is the object aimed at in laying the road in alternate bays instead of continuously. Further, in time water is bound to percolate into the joint, even if it is filled up with mastic ,and will eventually destroy the steel. Adjoining slabs can be kept level, without running the steel through them, by "interlocking" the concrete. See *Figs.* 3 *a*, *b* and *c*.

Fig 3a Plan of Suggested Interlocking Joint.

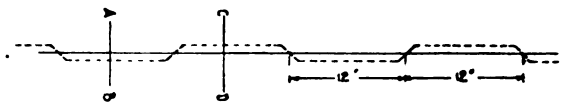
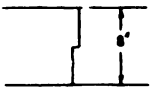


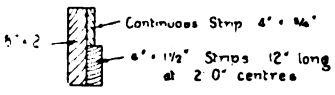
Fig 3b Section on A B

Fig 3c Section on C D



On the upper face of the road the joint is a straight line The lower halves of the two adjoining slabs consist of alternate insets and offsets, locking into one another a distance of ¾ inch. The shuttering for this is shown in *Fig.* 3*d*. This is not to be confused with a simple stepped joint, in which the slab which projects at the base is free to sink under the traffic load.

Fig 3d Shuttering for Joint.



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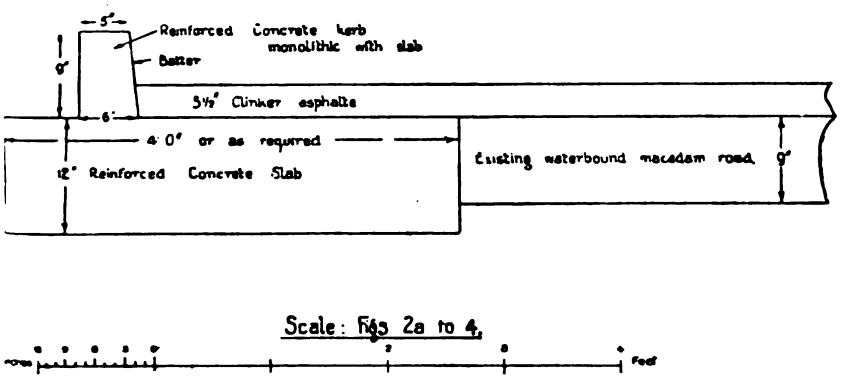
(*b*) There would appear to be no advantages gained in making ¾-inch the limiting size for the aggregate in the upper layer. In his opinion large aggregate up to, say, 2½ inches, is definitely superior, as the larger stones are more firmly fixed in the slab, and are also less likely to crush when a heavy load comes on them.

Improvement of an Old Road.

B. This road is an old waterbound macadam one, with metalling about 9 inches thick, in poor condition. It is being widened to 30 ft. by means of concrete slabs a foot thick on each side. (See

Fig 4. Improvement of Existing Road.



Scale: Figs 2a to 4.

Fig. 4.) The slabs and kerb are reinforced with some sort of mesh, but details were not available. Concrete kerbs are stated to be quite satisfactory so long as the inner face is given a batter. Without the batter they are liable to be chipped and cracked by wheels that graze them. They are much cheaper than stone kerbs.

When the concrete is in position a layer of clinker asphalte 3½ inches thick is laid on top of both the concrete and the macadam. It is expected that the road will then be able to stand the traffic to which a second-class road is subjected.

A very interesting point about this road is that it is being "super-elevated" at the curves, *i.e.*, the road slopes evenly right across from side to side instead of being higher in the middle than at both sides. With ordinary camber, of course, the traffic that should keep to the outside of the curve comes into the middle of the road or even right across, as it is difficult to drive round a curve with the camber against you.

"Super-elevation" obviates this danger and thus also prevents the road from getting more worn in the centre and inside than

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at the outside, as generally occurs; and there do not appear to b any important disadvantages attached to the method.

W. A. FITZG. K.

WORLD'S SHORTAGE OF LEAD.

THERE are indications from the technical building journals tha a serious shortage in the supply of lead is imminent, and that th price of leaden pipes and fittings will tend to rise again i consequence.

During the period April to August last, lead was selling a approximately £32-£34 per ton. In September the price droppe to £33 15s., but to-day it has reached £48 per ton.

The world's consumption of this metal is now far in excess o production, the demand continuing to expand whilst the supply remains stationary. The output of some of the larger mines seem to be diminishing, and the production of some of the newer field is only increasing very slowly.

For the year 1923 the United Kingdom made use of 15,700 ton of lead, whereas more recently the consumption has been in th neighbourhood of 22,000 tons. The consumption on the continen has increased in even a larger ratio.

In roof work zinc may be substituted for lead, copper for weather ings, cast iron for weights, iron for pipes; generally speaking the substitutes, except copper, would be cheaper than lead.

D.M.F.H.

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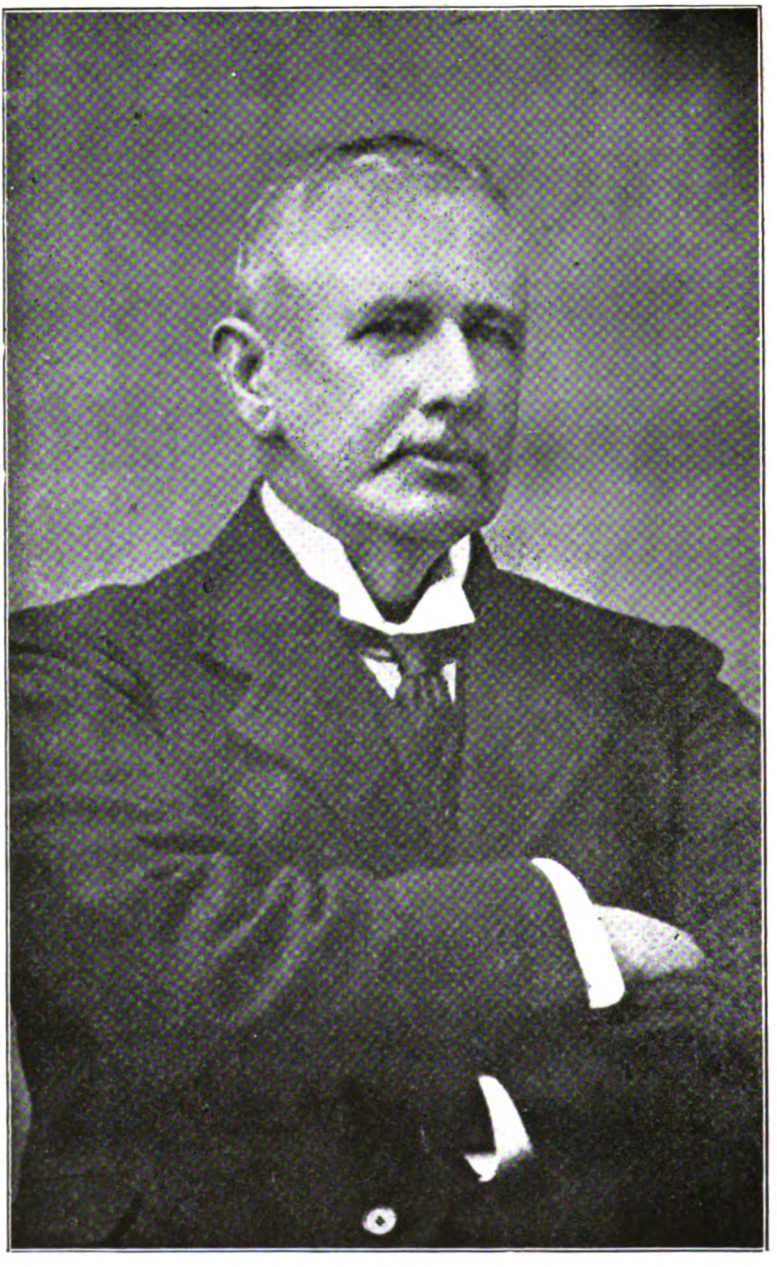

Colonel Henry Davison Love.

Photograph by Herbert Norris, *Newton Abbot.*

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MEMOIR.

COLONEL H D. LOVE.

COLONEL HENRY DAVISON LOVE, R.E. (retired), of Moorlands, Chagford, Devon, who died at Exeter on the 25th October, 1924, at the age of 72, made some important contributions to our knowledge of the establishment of British influence and authority in Southern India. Educated at the Tavistock Grammar School and at Bath, he entered the Royal Military Academy at Woolwich, and was commissioned to the Royal Engineers a few days before completing his 20th year. After a brief period of Home service he was admitted to the Indian establishment, and in 1876 joined the Queen's Own Sappers and Miners at Bangalore. He acted several times as Deputy Consulting Engineer for Railways, Madras, and now and again was on special duty in the Military Department. At the beginning of 1880 he was appointed Principal of the Civil Engineering College at Madras, and held the post until his retirement from the Service 27 years later. A man of great charm, he won the affectionate regard of staff and students, and set them the example of wholehearted study. In addition to many papers on technical subjects, he wrote a manual on hydraulics, published in 1887.

Colonel Love will be best remembered, however, for his non-professional studies, which were directed to Anglo-Indian history. In 1903, at the request of Lord Ampthill, he compiled an illustrated descriptive catalogue of the pictures in Government House and the Banqueting Hall at Madras, which is the only thorough one of its kind in relation to gubernatorial residences in India. His most important work, brought out in 1913, six years after his retirement, was his *Vestiges of Old Madras* in the Indian Record Series. The undertaking was laborious, requiring years of research, and entailing much wearisome copying of old documents; but the labour was well repaid by the three volumes and the separate index (compiled by the author with characteristic care) taking their place as the standard authority on the origins and development of our association with South India down to the beginning of the nineteenth century. The "Vestiges" throw a clear light on the life of the early English settlers; on the appalling political confusion of the country as they found it; on the sufferings of the people, and the benevolent and kindly attitude of the English to them. Subsequently Colonel Love compiled for the Historical Manuscripts Commission a calendar of the papers of Sir Robert Palk, sometime President and Governor of Fort St. George, Madras, covering the period of 1767-

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1786. These papers are now deposited in the Exeter Public Library. Colonel Love lost his wife some years ago, but had in his daughter an enthusiastic assistant in his literary work.—(*Extract from the Times of 4th November*, 1924.)

Colonel Love was the elder son of Henry Love, of the English Civil Service, and was born at Beaumaris in the Isle of Anglesey. At Woolwich he became Senior, or, as it was then called, Responsible, Under Officer, and passed out top of his batch, gaining the Pollock medal. In 1879, in Bombay, he married Janet Arnold, daughter of the late Captain William Orcher Lloyd, Royal Artillery, and widow of Lieut. Daniel Leland Litton, Royal Engineers. The *Report on the Palk Manuscripts* was published by H.M. Stationery Office, and reviewed in the *R.E. Journal* in March, 1923. Colonel Love also wrote a *Manual of Applied Mechanics*.

Major-General J. A. Ferrier, C.B., D.S.O., writes: "Love was a fine mathematician and naturally well versed in engineering, especially hydraulics, and conversation with him on any engineering subject was always enlightening. But he was not only an engineer, but a man of culture, with an agile brain capable of assimilating any subject at short notice.

"I consider him one of the most brilliant of my contemporaries, and always deplored the fact that he had been hidden away in a position that brought him so little before the public eye. He and his wife had many friends, most of whom, I fear, have passed away, but those that survive will, I think, share with me in regret for the loss of a friend who was always helpful, thoughtful and kind, and never worried."

One of these friends, the widow of an officer of the Corps, writes: "I never knew such a wonderfully kind, good man—so thorough in everything he undertook; and I know of so many cases when persons left as I was turned to him for advice. . . . . His loss to many can never be filled."

COLONEL F. P. RUNDLE, C.M.G., D.S.O.

FRANK PEVERIL RUNDLE was born at Plymouth on 13th October, 1871. He was a grandson, on the maternal side, of Captain John Edward Davis, R.N., who came of an old naval family going back several generations, and who accompanied Sir James Ross on the *Erebus* and *Terror* expedition to the Antarctic in 1839-43.

Rundle was educated at Mannamead School at Plymouth, and at Charterhouse ("*Hodgsoneites*"). From Charterhouse he passed direct to the "Shop" and got his commission in 1889.

After his two years at Chatham he went to Sheerness as a Submarine Miner, and thence in the same branch to Karachi in 1895.

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Colonel F. P. Rundle, C.M.G., D.S.O.

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He first saw field service as an attached Officer with a company of Bombay Sappers and Miners with the Malakand Field Force in 1897.

He subsequently served as a Submarine Miner, a Divisional Officer R.E., and a M.W.S. Officer at Bombay, Aden, Harwich, Rangoon, Calcutta and Secunderabad.

East Africa was the theatre which claimed his services during the Great War. Arriving there in May, 1915, he served there practically continuously until after the Armistice. His duties brought him into personal touch with Generals Smuts and Van Deventer, under whom he rose to the position of Chief Engineer. His services were recognised by the awards of a Brevet lieutenant-colonelcy, the decorations of C.M.G. and D.S.O., and several mentions in despatches.

After the Armistice he returned to India and continued to serve there until his retirement in 1923.

He died suddenly in London on March 31st, 1924, from an attack of angina pectoris, probably largely induced by the strain of unceasing work and responsibility throughout the War years in a trying climate.

As regards his activities outside his profession—without being to any extent a betting man—Rundle was a devoted follower of horse racing. At one time a Steward of the West of India Turf Club, he was at the time of his death a subscriber to Newmarket and a member of Epsom, Doncaster, York, Aintree, Windsor, Newbury and other racing clubs.

No man who acquired his friendship has ever had a more staunch, loyal and stouthearted comrade. His downrightness and entire disregard of his own personal loss or gain in adhering to the line which he judged to be the right one, were the outstanding characteristics which probably won for "Bull Rundle" the sobriquet by which he was known to his large circle of friends.

His death has deprived those friends of the genial companionship of a personality which can never be replaced.

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BOOKS:

LA BATAILLE DE L'YSER.

Examen critique d'une étude de M. L. MADELIN.

La Bataille de l'Yser (Brussels, Van Sulper), by Colonel C. Merzbach, of the Belgian General Staff and head of the Belgian Historical Section, is a critical examination of the writings of a Frenchman, M. Madelin, on the war, as they affect the Belgians. That he should have cause for complaint is small wonder; M. Madelin's publications have been full of errors and misconceptions as regards the British share in the War, but this is usually the case when civilians write about any war, recent or ancient. M. Madelin gives the French Commanders credit for everything. He says that General Pau went to Antwerp to induce King Albert to withdraw his troops and take the left of the line. As a matter of fact, General Pau never came into Antwerp, but he did come to Belgian Headquarters at Selzaete after the Belgian Army had left Antwerp and was already on the left of the line. It was General Foch, we are told, who suggested flooding the Yser to cover the Belgian troops. Here again, as a matter of fact, General Foch proposed to make the St. Omer-Calais inundation *behind* the Belgians, so that then they would have been cut off. M. Madelin's publications contain discourteous as well as inaccurate statements, *e.g.*, " The Belgian Army was full of courage, but besides being tired out, its soldiers could not have the solidity of our 'old troops,' for our men, who since the 15th August had taken part in so many fights, had already the faces of veterans." Yet, as Colonel Merzbach points out, the Belgians had been fighting since the Germans entered their country on the 4th August. The French author gives all the credit for stopping the Germans on the Yser to the " red breeches " of General Grossetti at Nieuport and the Marines of Admiral Ronarc'h at Dixmude. Colonel Merzbach considers that this kind of thing might be forgiven to a lecturer carried away by his subject, or to a poet relying on his imagination for his facts, but it is not creditable to "an historian by profession, *agregé* (qualified at the highest standard examination) of history and geography, doctor of letters, and candidate for the Academy," and, we might add, one of the regular contributors to the *Revue des Deux Mondes*. No military writer, we feel sure, would make such claims for the French or cast doubt on the extraordinary resistance offered by the small Belgian Army to the gigantic and barbarous forces of the old German Empire.

J.E.E.

THE MILITARY USES OF ASTRONOMY.

By MAJOR F. C. MOLESWORTH, R.E., F.R.A.S. (London: Longmans, Green and Co.) 1924. pp. 112, with diagrams.

MAJOR Molesworth has written an excellent little introduction to the study of astronomy, which can be safely recommended to any one who

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is beginning the subject. Many of the practical hints will be found of real value to soldiers, if only these hints can be kept in the memory. And that is the real difficulty. An officer has nowadays to learn and remember so much that is essential in the carrying out of his duties, that matters of less, or only occasional, importance must sometimes go to the wall. In his mental equipment he cannot follow the example of the White Knight.

But still there are some elementary astronomical facts that every officer might, perhaps, be expected to have at his disposal, such as rough ways of finding the North, simple methods of determining local time, and so on. These he will find clearly expounded in the book under review. Curiously enough, however, practically nothing is said about sun-dials; though these may often be found of real use, especially in standing camps away from railways and telegraphs. But perhaps the author had in mind the employment of wireless.

Nine men out of ten, when asked to describe the value of elementary astronomy to a soldier, would instance the case of night-marching. Now, there is, in reality, very little to be said on this subject; in this book we find three pages on *Direction by the Stars*, and in the official Manual there are only a few paragraphs. To march by the stars involves no knowledge of the names of the stars, and, indeed, no knowledge of astronomy, except the elementary fact of the earth's rotation. But in night marching the utmost care is required in simple details, and, in any case, one should not expect—except in very favourable circumstances—the rather high degree of accuracy indicated by the author, namely, an error of less than one degree, say, thirty yards in a mile. But in this sort of thing practice makes perfect, and it can be imagined that a specialist in the night-marching of the kind described might get very good results; but, in any case, in important operations an expert would certainly be called in, as happened at Tel-el-Kebir. In this connection Major Molesworth quotes "450 *Miles to Freedom*," which describes the way in which eight officers found their way by azimuth charts.

The book contains some labour-saving sun azimuth and altitude diagrams, and the reviewer was about to say that these alone were worth the cost of the book, when he discovered that there is no price marked.* However, the diagrams may often serve a good purpose, and not only for purely military needs. There is also a chapter on that tricky subject, the Tides. The Bombay chart seems to have been generalised into rather too angular a series, and it may convey a somewhat incorrect impression as to the character of the tide curve; but the matter is not important, as it can be but rarely that a land officer is seriously concerned with tidal matters.

The book, as a whole, can be recommended, even to those who have gone through some period of pleasureable instruction in Astronomy at the S.M.E.

C.F.C.

* The price is 3s. 6d.—Ed., *R.E.J.*

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MATHEMATICS FOR TECHNICAL STUDENTS.

By E. R. VERITY, B.SC., A.R.C.SC., Head of the Department of Mathematics and Mechanics, The Technical College, Sunderland. (London: Longmans, Green & Co.) Price 12s. 6d.

THIS treatise is mainly devoted to Algebra, commencing with simple equations and up to the binomial, logarithmic theorems, and the graphical solution of cubic equations. There are four chapters on Trigonometry, which subject is dealt with as far as the solution of triangles, two on Projections and Solid Geometry, one on Simple Harmonic Motion, one on Areas and Centroids, one on Moments of Inertia, two on Kinematics; the last six chapters contain an introduction to the Calculus.

The book is very elementary throughout, and though of no use to the serious mathematical student, should appeal to that very wide class which possesses little mathematical knowledge.

No pains have been spared to obtain lucidity, and a great deal of useful information is given in a moderate compass and at a very reasonable price.

Special stress has been laid on graphic methods. There are numerous examples of an instructive and practical character.

J. M. WADE, *Lieut.-Colonel* (B.Sc., London).

SOME ASPECTS OF IMPERIAL COMMUNICATIONS.

By Major A. V. T. WAKELY, M.C., R.E. (Sifton Praed.) Price 9s.

MAJOR Wakely has, in the volume under review, brought together much interesting and valuable information relating to Imperial Communications, using the latter term in the wide sense as applying to "means of transport" as well as "means of inter-communication"; the great sea routes, the air routes of the Empire, Imperial railway communications, inland waterways, mechanical transport, sea cables and land lines and wireless inter-communications all receive careful attention, and, in many cases, the information given in the volume has been brought up to date, so as to include the latest developments in the subject under treatment. The volume, which is illustrated and also provided with a number of plates giving information on certain matters in graphic form, should appeal to many classes of readers, but to none more so than those who follow the profession of arms, whether as sailors, soldiers or airmen, to whom all that appertains to the communication services has at all times been a matter of deep concern and importance. The strategical aspect of the several branches of the subject receives considerable attention; *inter alia*, the defence of sea communications, and the strategic aspects and problems of the railways on the North-Western Frontier of India, and of those in Canada and Australasia are discussed, and some of the principles involved in the situations dealt with are clearly stated. Further, in many instances, Major Wakely reviews the essential elements or requirements of particular branches of various communication services; for example, in the case of port organisation, the elements of a port are classified; again, in the case of air routes of the Empire, the

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requirements of commercial aviation are given ; and so on. In this way, the non-expert is put in a position readily to grasp the nature of the problems that have to be dealt with in connection with Imperial Communications, and the volume should, therefore, achieve its purpose, which, the author tells us in his preface, is an endeavour on his part to outline the various problems relating to his subject in language intelligible to non-technical readers. As will be seen from the foregoing statement of the scope of the work, the ground covered in the volume extends over a very wide range ; however, in regard to recent progress the matters left untouched in the volume are exceedingly few, the most noticeable, perhaps, being the absence of any mention of the recent advances in the field of multiple telephony ; the achievements in the United State of America in this field are very remarkable ; for instance, in 1923, a single line between New York and Chicago, a distance—by route—of nearly 1,000 miles, was satisfactorily carrying 85 telephonic and telegraphic communications simultaneously (*vide Journal I.E.E.*, vol. 61, No. 319—June, 1923—at p. 634). The example given here of the progress made certainly relates to American practice, which admittedly leads the way in the telephone field ; but mention is made of this achievement as there must be a field in our vast dependencies and colonies, such as India, Canada and Australasia, for a similar utilisation of costly long-distance telephone lines. From the foregoing remark, it must not be assumed that Major Wakely has overlooked important progress in the telegraph field ; such is not the case, for on p. 136 of his work, he calls attention to the " interesting development of ' wired wireless ' "—of which the American achievement mentioned is but an example—and states that on the route " via Eastern " the cable conductor is not only used for duplex working, but that it is simultaneously utilised for the transmission of a third message by " wired wireless." As another recent development in the telegraphic field, Major Wakely makes a reference to the " loaded " cable laid in September, 1924, by the Western Union Telegraph Company between Fayal (Azores) and New York, the first tests of which showed that in this particular case the increase of the carrying capacity was nearly four-and-a-half-fold as compared with a non-loaded cable between the same points, viz., whereas the normal cable had an output of 75 words, the new " loaded " cable has an output of 340 words (1,700 letters). The loading of cables is not, as a matter of fact, a very recent innovation ; it has been in practical use for at least a couple of decades. Originally, one or more layers of soft iron wire or tape were wound spirally over the copper conductor, and in this way the carrying capacity of the circuit could be increased nearly two-fold. Very recently a new alloy, now known as " permalloy," was discovered, and it is found that if instead of winding soft iron wire spirally round the conductor of a submarine cable it is similarly served with a " permalloy " tape, the transmission efficiency of the copper line is very greatly increased ; indeed, as the results on the " via Eastern " route given by Major Wakely show, " permalloy " produces results as a " loading " material for cables which are more than two-fold more beneficial than those obtained formerly by the use of soft iron wire or tape. What is a serious slip occurs at p. 139 of the volume: dealing

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with the problem of wireless transmission, it is rightly stated that signals sent from a transmitting station can be received by any receiving station which is within range, and is properly tuned to the particular transmitting station. The author then proceeds to explain why it is that neighbouring transmitting stations may cause interference with the signals of one another, and states that this is because " the medium used by all stations is the same, viz., the air " ; true, the medium is the same, but whereas sound waves are propagated by means of and through the air, on the other hand, physicists attribute the propagation of radio waves to the existence of an all-pervading ether, and, therefore, scientifically, it would be incorrect to say that the medium through and by means of which radio waves are transmitted is air. In dealing with the question of the Empire Wireless Chain, Major Wakely frankly recognises that he is touching upon a highly controversial subject ; he therefore contents himself, rightly, we think, in simply setting out some of the well-known arguments which have been publicly advanced for and against State-owned Wireless Telegraph Stations being erected in England. One of the chief a guments against State-ownership is in certain well-informed quarters not so delicately stated as by Major Wakely ; the opinion is held in these quarters that the real reason for the failure of a Government Department properly to handle so highly technical an enterprise as the Empire Wireless Chain arises from the fact that the complete control of the scheme is vested in non-technical officials, who do not take the same broad view of their proper sphere of responsibility in the staff organisation as do the financial and administrative officials of a private concern ; consequently, in a Government Department the technical officers have neither the status nor the authority necessary to enable them efficiently to carry out their duties. It is also suggested that hence it is that Government Departments do not succeed in recruiting, and if they do temporarily succeed, then in retaining, in the service of the State, for their technical branches, men of the same eminence in their profession as those who throw in their fortunes with a private firm and make a successful career. Major Wakely has dealt ably with the many problems he discusses in his work, which can be thoroughly recommended to all who take an interest in or are concerned in any way with the subject of Imperial Communications.

W.A.J.O'M.

REGULATION OF RIVERS WITHOUT EMBANKMENTS.

By F. A. LEETE, Imperial Forest Service, India, Chief Conservator of Forests, Burma. (Crosby Lockwood and Son.) Price 30s.

THIS book is an interesting study of the habits of hill torrents discharging into plain , bringing down enormous quantities of silt in suspension, and building up banks for themselves where the silt is precipitated.

That this building up of silt banks does occur when the water spreads over the plains and loses its velocity is well known, but training works to utilise scientifically this great power for reclamation, and to deposit the silt where it will be beneficial, have only recently been undertaken in Burma to a large extent.

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The problem in Burma was intimately connected with logging operations, but the results obtained have been beneficial to the country at large, areas have been reclaimed for agriculture and villages safeguarded and protected from floods.

Although logging operations are not usually met with, there are many cases where the problem arises of training silt-laden rivers through flat alluvial plains.

The first chapter of the book gives a summary of the problems presented in the particular case, a brief description of the earlier efforts to control the torrents, and the final solution as worked out.

Chapters VI. and VII. describe in greater detail the methods by which training without artificial embankments is carried out, the intermediate chapters dealing with the problems which had to be solved. The three final chapters deal with Engineering Notes on individual streams, Statistical Data and Extracts from Old Reports, in which is included a Note by Lieut.-Col. (afterwards Sir C. C.) Scott-Moncrieff, R.E., C.S.I., written in May, 1882.

A more correct title for the work would have been " the regulation of rivers without *artificial* embankments," as the regulation is carried out by embankments raised by the streams themselves from their silt-laden waters. In the case of the seven streams dealt with, draining 560 square miles in the hills, the amount of silt brought down has been sufficient to reclaim and raise above flood level 10,000 acres of swamp land, in eight years, and the reclamation is progressing steadily at the rate of 2 sq. miles a year. When it is considered that this swamp land is raised apparently from 10 to 15 ft. in height, some conception of the work done by the streams can be formed.

It is not possible to explain the system in a few words, but all who are confronted with similar problems, either great or small, cannot but be benefited by the perusal of this book.

Apart from the value of the work, the book is most interesting to read, and contains 72 excellent photographs and sufficient maps for reference.

D.K.E.

THE WAR EFFORT OF NEW ZEALAND.

Edited by LIEUT. H. T. B. DREW, N.Z.E.F. (Whitcombe and Tombs, Ltd.) 1923.

THIS book, which is the fourth and last volume of the Official History of New Zealand's effort in the Great War, has been presented to the Corps' Library by the High Commissioner of New Zealand, and contains accounts of the Minor Campaigns, including the occupation of Samoa and the Senussi campaign, in which New Zealanders took part, and reports on the work of the various services and of the work at the Base. An interesting preface, written by the Editor, Lieut. H. T. B. Drew, gives useful statistics of the war effort of New Zealand, both in men and money, and also in supplies of meat and other produce, 160 million pounds' worth of which was shipped to the United Kingdom under the Imperial requisition.

F.E.G.S.

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LE COMBAT DE L'INFANTERIE.

(Etude analytique et synthétique d'apres les reglements. Illustrée de cas concrets de la guerre 1914-1918). By COLONEL ALLÉHAUT. (Berger-Levrault) 10 francs.

"ENGINEER officers," says Engineer Training," must understand the methods . . . .employed by the infantry, with which arm they will be most closely associated in battle." Infantry Training is therefore, doubtless, an open book to us all. But experience shows that something more is required to clothe the principles of the Regulations in flesh and blood. The tactics and procedure of infantry are in their essence a psychological study. We must know what they, as men, can and will do before we ask them to do it. Our study will be barren if we cannot give it a human form, and on the human side the Regulations are, perhaps necessarily, incomplete. We need to be able to illustrate and to test them with the touchstone of war experience, by the light of minor episodes of battle. The French army is fortunate in possessing a considerable and increasing literature designed to illustrate their war doctrines with detailed pictures from the late war: a literature which has but a small counterpart in our own military journals. It is therefore with pleasurable anticipation that one opens Colonel Alléhaut's " Le Combat de l'Infanterie," intended, as he tells us, to analyse and explain expressly for the benefit of the other arms the methods of the French infantry and to illustrate their official doctrine with concrete examples from war experience.

Nor, in his First Part—" Liaison morale infanterie-artillerie "—are we in any way disappointed. Colonel Alléhaut adds to a glowing enthusiasm for the French soldier the possession of that lucid yet dramatic style which distinguishes the French military writer. In three vivid pictures he illustrates the essential importance of the closest friendship, collaboration and mutual knowledge between the infantry and the supporting artillery. And he pleads for a less material outlook than is sometimes to be found among artillery commanders. It is the duty of the artillery, he says, to maintain the morale of the infantry by every means in its power. If it cannot hit the enemy, let us at least have the *illusion* of support, let us at least hear the cheerful sound of our own shells passing overhead.

Is it only due to a difference in the psychology of our infantry that his plea finds little, if any, echo in our own Artillery Training ?

But if the " First Part " provides an admirably human study, the " Second and Third Parts ": " Notions générales," and " Le combat du bataillon et du régiment " are in this respect disappointing. The exposition is complete, clear and logical; but as we proceed we feel the cold breath of regulation, the deadening influence of the *scheme* or diagram. Especially is this the case when Colonel Alléhaut is dealing with the " attack." We ask ourselves: is this true to life ? has it been tested in war ? will it work ? When he deals with the " defence " we are on firmer ground, since the French doctrine, as Colonel Alléhaut presents it, differs little, if at all, from our own. Engineer officers can read this portion of the book with considerable profit; and in the two pictures of defensive battle with which he concludes, one of an improvised front covering Amiens in April, 1918, and the second of a portion of the famous defence

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of Champagne front in July 15th, 1918, Colonel Alléhaut returns to his earlier form and concludes his study on a high note.

But if the bulk of his book will not greatly assist us to apply our own regulations, cannot we study it with profit as a convenient presentation of the French doctrine? Such a study lies to our hand already in a more convenient form in an able article by Captain Liddell-Hart which appeared in the issue of this Journal for April, 1922, and in a further article by the same author in the September, 1924, number of "The Fighting Forces"; though it must in justice be said that Colonel Alléhaut's interpretation goes some way to meet the criticisms to which the French doctrine was therein subjected.

It is in fact in his reasoned explanation of those differences from our own practice which Captain Liddell-Hart has noticed, that much of the interest of Colonel Alléhaut's presentation lies.

Only one point can be touched on here, but it is one of fundamental difference. The French have been accused of being, in attack, far too thick on the ground; of reverting to the pre-war errors of "building up the firing line" to obtain "superiority of fire" and of "direct reinforcement" of the leading echelon. The "normal" frontage of a *groupe* (consisting of a light automatic *equipe* and a rifle *equipe*, a total of twelve men) in the "échelon de feu" is 55 yards or one man to 4.6 yards. Compare this with our "normal" of two sections "up" on a platoon frontage of 200 yards, or an average of one man to 16.6 yards, and it will be seen that the French can hardly escape from the first of these accusations. Yet their doctrine is based on a logical argument, which runs as follows: In the early stages of a campaign or in open warfare we shall have neither the guns, nor the ammunition, nor the knowledge of the enemy dispositions which will allow the overhead covering weapons completely to ensure the progress of the infantry. Infantry must therefore be prepared at any point on the front to fight their way forward with their platoon weapons. But infantry cannot progress unless the fire of the defenders is continuously neutralised. And to ensure such continuous neutralisation we require in the "échelon de feu," one *groupe* for the 50 metres of front, which is all that each can cover with its fire; more than this leads only to heavier losses, less than this will not provide the necessary fire. This density must, therefore, be maintained throughout the attack; gaps due to loss of direction or to *groupes* being placed "hors de cause" must be filled if the progress of the attack is to be maintained. Hence one of the duties of the support and reserve units is to "reinforce" the "échelon de feu," not, be it observed, to build up the firing line to a greater density but to maintain the minimum density necessary for progress.

The argument is logical—where has the error crept in? At what point does it depart from the teaching of our *Infantry Training, Vol. II*, Amendment 2? Is the error due to a misreading of experience, or to a difference in national characteristics or in organisation? Or is it due to a difference in the type of warfare which our respective regulations contemplate? What are the factors which determine infantry frontages? On what arguments and experiences are our own normal frontages based?

These are questions on which the reader can profitably exercise his mind. We could wish that Colonel Alléhaut had proved the correctness

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of his premises by further historical examples. But we still more greatly wish that more officers of experience would utilise our military periodicals to demonstrate the correctness of our own doctrine in this and other matters by battle pictures related with an equal skill.

L.V.B.

THE TESTING OF HIGH SPEED INTERNAL COMBUSTION ENGINES.

By ARTHUR W. JUDGE. (Chapman & Hall, Ltd.). Price 25s.

This volume deals primarily with the engines of automobiles and aircraft, but the bulk of its contents is applicable to other types of Internal Combustion engines.

Tests are classified under three heads, Routine and Acceptance Tests, Tests of new types to ascertain the effects of changes in design, and Analytical or Research Tests.

Tests under these different heads are described in a clear concise manner, the results of tests being shown in easily read graphs. Test sheets are given showing the best way of recording test data, but the majority of the tests require apparatus which is not as a rule available in the service.

Many types of absorption Dynamometers are described, from the simple rope brake to the electric swinging field Absorption apparatus.

Though practically none of these dynamometers are to be found in the service, no one, after reading the chapter on the measurement of Brake Horse Power could fail to pick up information that might be of great assistance to him if called upon to take the B.H.P. of a high speed engine with only improvised gear.

The taking of pressure measurements and indicated horse power diagrams of high speed I.C. engines is fully described, but it is obvious that accurate instruments are required before any useful results can be obtained.

The chapters on pressure measurements are full of interest, but the actual taking of such measurements is a laboratory business, and is the work of the specialist.

Many Indicator and Light Spring diagrams of high speed engines are reproduced; most of these are, however, to illustrate faults in the indicator apparatus rather than faults in the engines under test.

Various forms of Pyrometers used in taking temperatures of valve heads, combustion chamber walls, etc., are also described.

A chapter is devoted to notes concerning the road tests of the chassis of road vehicles as carried out for commercial and research purposes. No attempt is made in these at really accurate measurement of quantities, and apart from the accelerometer and drawbar tests, the road trials described are mostly of a type that could be carried out on service vehicles and are therefore of interest to the service reader.

The volume under review is intended primarily for internal combustion, in fact for specialists who have at hand the necessary apparatus for making accurate tests. The accurate testing of high speed I.C. engines is outside

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the scope of the ordinary R.E. Officer, but as a potential user of internal combustion engines he should become acquainted with the methods of testing employed, and as such will read this book with great interest, and will probably learn a lot in so doing. G.C.G.

DU HAUT DE LA TOUR DE BABEL: COMMENTAIRE SUR LA PREPARATION A LA GUERRE ET LA SITUATION STRATEGIQUE DE LA BELGIQUE EN 1914.

By LIEUT-GENERAL DE SELLIERS DE MORANVILLE. (Paris: Berger-Levrault.) 8 francs.

The general, who was Chief of the Staff of the Belgian Army at the outbreak of war in 1914, has written this book to correct the errors and confusion which writers of history will meet with in many published documents dealing with the military side of Belgium's share in the outbreak of the Great War, and which he likens to the confusion of tongues during the building of the Tower of Babel. The greater part of the book is taken up by an exposition and criticism of the French and German plans of campaign, but the interest centres in the third part, describing those of the Belgian Army. The difficulties of preparation of a scheme of defence were very great. The uncertainty as to which of their neighbours would violate their territory, the complication of the Dutch Limbourg, with its *tête-du-pont* on the left bank of the Meuse at Maestricht, and the incompleteness of the reorganisation of the Belgian Army, all had to be considered. On the 30th July the General presented to the King his plan of concentration of the Field Army, of one Cavalry and six Infantry Divisions, in the quadrilateral Saint-Trond—Eghezée—Hougarde—Tirlemont, but the King, anxious to give no possible cause of offence to Germany, moved it further west to Tirlemont—Perwaz—Louvain—Wavre. Later on, the 3rd and 4th Divisions were left in Liège and Namur, from which garrisons both were fortunate to escape, though with serious loss of men and material. There seems to be no doubt that the defence of Liège, so glorious to the Belgian Army and valuable to their *moral*, did not actually cause any delay in the programme of the German *aufmarsch*, but the General claims that, on the 18th August, the Field Army on the Géthe did actually delay the right of Kluck's army for more than a day, and procured a very profitable gain in time to the armies of their Allies. Against a powerful nation like Germany, Belgium could not hope to hold her territory, but the preservation of her Field Army was a political necessity of the first order. F.E.G.S.

IMPERIAL MILITARY GEOGRAPHY.

CAPTAIN D. H. COLE, M.B.E., Army Educational Corps. 2nd Edition. (Sifton Praed,) 10s.

A NEW edition under a shortened title has just appeared of Captain Cole's book, originally entitled "Elementary Imperial Military Geography." The book needs little introduction to military readers, especially those who

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have recently found it necessary to face the examiners who dog the footsteps of Junior Officers. In the short eleven months of its existence the book has become a standard work on the subject, and is worthy of the closest study by all those, military or civilian, who desire to understand the military problems of the Empire in their widest sense. The information though full of detail is presented in an attractive and readable form.

In the new edition Captain Cole has included a great deal of valuable matter, especially in the direction of political and strategical deductions based on the mass of detailed information which the book contains. Among the subjects which have received extra attention may be mentioned Imperial Resources, Oil, the Middle East, and the Gateways of India. Certain minor details of the forces of the self-governing Dominions have wisely been omitted. Some of the Maps with which the book is very well supplied, have been enlarged and redrawn; bibliographies have been appended to each chapter; a valuable index, without which no book of the kind should ever be published, has been added; the appendices dealing with the methods of government of the Dominions and Colonies have been enlarged and rearranged; and last but not least the price, in spite of the considerable enlargement, has remained at 10s., which in view of the excellent paper and printing and the liberal supply of well drawn maps, cannot be considered excessive.

The study of this book is almost a necessity for Officers preparing for the Staff College entrance or Promotion examinations.

R.P.P-W.

NOTICE SUMMAIRE SUR L'EMPLOI DES EXPLOSIFS.

Par R. DEGUENT, Major du Génie, et F. VAN DEN BERGHE, Capitaine Commandant du Génie. Brussels: Imprinterie du Ministere de la Défense Nationale. 12 francs.

THE thorough and systematic demolition of communications in an area has become to be recognised as so important a strategical weapon, that the publication of this little book has come at an opportune time. Written by Major Deguent and Captain Van den Berghe of the Belgian Artillery and Engineer School and published by the Belgian National Defence Ministry, it is full of useful information, tables, formulæ, for demolitions in the field. The formulæ look at times alarming but the diagrams and examples are clear. Unfortunately the demolition of ferro-concrete is only lightly touched on and the authors recommend the detonation of a preliminary charge to lay bare the reinforcement.

A useful table gives the equivalent explosion value, in T.N.T., of various shells, which may have to be used when explosives are scarce, and the question of organisation, placing and damping of charges is fully dealt with.

The authors rightly lay great stress on the cardinal point of all demolitions in the face of the enemy. *They must not fail.* Every care, forethought and preparation must be taken to ensure success. We are not given a second chance.

E.H.K.

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CHARTS FOR BATTLE LANDSCAPE TARGETS.

Designed by CAPTAIN D. P. J. KELLY, M.C., A.E.C. (Gale & Polden; Aldershot), 6d. post free.

The object of these charts is to assist in making scale models for miniature ranges up to 25 yards. One set of graphs shows the necessary dimensions for a model to represent correctly an object of known size at various ranges. Another gives the rate at which any model, from an infantry column to an aeroplane, should be made to move in order to give a correct representation at any range up to 2000 yards. Useful hints as to operating models are also given.

I.S.O.P.

MANUEL PRATIQUE DE TIR ET D'APPRECIATION DES DISTANCES.

By CAPITAINE A. VILLEDIEU. (Berger-Levrault), 2 fr. 50.

This is an elementary pamphlet on musketry instruction and judging distance, with illustrations. It has some value as a means of learning the French technical terms relating to aiming and firing, ballistics, the parts of the rifle, etc. Among its hints to pupils are the following:—"Evitez absolument l'usage de l'alcool et du tabac; faites de l'hydrothérapie le plus possible, et fuyez toute occasion de débauche."

I.S.O.P.

MAGAZINES.

REVUE MILITAIRE GENERALE.

(*August*, 1924.)—*The 4th Army Corps on the Ourcq.* The article by General Boëlle is concluded, describing in considerable detail the events of the 8th and 9th September, and is illustrated by two clear maps. On the 10th the general retreat of the Germans commenced.

Les "Engins d'Acompagnement." The article by Commandant Biswang is continued, reviewing the weapons adopted or on trial in (*c*) Russia, (*d*) the United States), (*e*) Italy, and (*f*) Germany. The two latter are dealt with at some length. (*To be continued.*)

The 6th Cavalry Division and its Tanks at the Grand Manœuvres on the Rhone. By X. (probably an officer of high rank). The writer was privileged to follow the movements of the tanks at close quarters, and offers criticisms in regard to their employment, and suggestions for better organisation and action in future. To begin with, the realism of the manœuvres was marred owing to all but one of the regiments in the Cavalry Division having strengths of only one-third of their establishments, and to none of them having worked in conjunction with tanks beforehand. The result was that the Division was like a sick man encumbered with weapons he was too weak to wield, and the umpires had to intervene at least once to rectify incongruities in the dispositions adopted. The views advanced are instructive and worthy of consideration. (*Accompanied by a map* 1/80,000 *of the manœuvre area, and a diagram* 1/200,000.)

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Military Chronicles of Economic Questions. M. Pierre Bruneau this month deals with the activities of the Chief Commissioners in Syria—General Gouraud till 1923, and subsequently General Weygand. Both have shown themselves talented economists and financiers as well as able politicians and military leaders. Chambers of Commerce and sea-ports have been ameliorated and improved, roads and railways repaired, separate states brought into one federation, customs reorganised, a colonial office and model farms instituted, with an experimental cotton station in the plains of Tripoli, and commerce stimulated by a fair at Beyrout. Irrigation is receiving attention and the valley of the Orontes is being developed for the cultivation of cotton. Motor transport is increasing, and it must be remembered that the service between Beyrout and Bagdad is not entirely English, and must traverse Syria to link Palestine with Iraq.

Books. La Belgique et les Belges pendant la Guerre. By Commandant A. de Gerlache (Berger-Levrault). Sketches the history of Belgium since its separation from Holland in 1821, and analyses the conditions of its neutrality and the circumstances which led to its participation in the war. The remainder of the book relates the atrocities of the invasion of 1914, the heroic days of the Yser, and the physical and moral sufferings of the inhabitants.

Les Conquérants du Tchad. By Colonel O. Meynier (Flammarion). An account of the progress of the French in this district of equatorial Africa from pioneer days to the present time.

L'Effondrement. By M. Philipp Scheidemann (Payot). Written in the form of memoirs, this book describes as a succession of episodes the critical periods in Germany from 1914 to the Armistice and the months following it. It relates in full detail the part played by the social democrats from their resolution to vote the war credits on 3rd August, 1914, their impassivity when Belgium was invaded, their agreement with the Austrian socialist annexationists, their vain struggles for a "*paix d'entente*," and against the submarine war. Precise details are given of the internal situation of Germany, social and economic, especially of the strikes of 1917 and 1918. Based on documents of indisputable veracity, this narrative of events shatters the fable of the "dagger thrust in the back," and clearly explains the attitude of the various political parties in Germany at the present time.

(*September*, 1924.)—*Ludendorff's Battles on the Russian Front.* By General Camon.—This article begins with a disquisition on the systems of Hannibal at Cannae, of Epaminondas at Leuctra, of Frederick II., Napoleon, Moltke and Schlieffen, and shows how the German generals in the late war were influenced by the views of the last named, which were in reality a return to those of Hannibal. An interesting article. (*To be continued.*)

Infantry in Open Warfare. By Commandant Padovani.—Posing as axioms (1) that infantry cannot perform evolutions when exposed to the fire of hostile infantry, and (2) that in order to be able to advance superiority of fire power must be developed, the writer studies in Chapter I. the offensive action of infantry, dividing it into five phases: (1) the approach, (2) making contact with the enemy, (3) the attack, including

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the assault, (4) holding the ground won, and (5) exploiting the success. He then considers the appropriate action of the various commanders, regimental, battalion, company and section, the orders they should issue for each phase, and their normal positions on the battlefield. (*To be continued.*)

Les "Engins d'Acompagnement." The article by Commandant Biswang is concluded. The French and German regulations are compared, the main differences lying in the greater number of heavy weapons attributed to the infantry by the latter, and in the allotment of "infantry guns," as they are called, from the earliest stage of an engagement. Chapter VI. discusses the weapons of the future, probably a heavy anti-aircraft machine gun, and a special "gun-howitzer," the essential characteristics of which are set out with much thought and detail, a battery of which, manned by gunners, should be the sole property of each regiment, with, perhaps, an extra battery per division as reserve. In Chapter VII. it is argued that an additional weapon, which would be useful, would be "powerful light artillery," a new name for the trench mortar, and that the caterpillar machine gun, which has been proposed, is superfluous and utopian.

Study of the Transport of a Division in Motor Vehicles. By Capt. Salmon.—The move selected for study is that of the French 38th Division in support of the light corps after the battles of the Marne. It shows what precautions it is necessary to take, road repairs, flank guards, night marches, and also that troops so moved can afford powerful support to the light troops pursuing a retreating enemy, but that they can only be put in motion behind a substantial cavalry screen. It demonstrates that mechanical progress does not diminish the importance of the old arms, infantry, artillery and cavalry, but can increase their efficiency.

(*October*, 1924.)—*Ludendorff's Battles on the Russian Front.* The article by General Camon is continued, and sketches in clear outline the strategy and tactics resulting in the German victories at Tannenberg and the Masurian Lakes. The former, a "Battle of Cannae," aimed at encircling, but with sensibly equal numbers, both wings of Sansanov's Army of the Narew, and, although the shattered wings escaped, the centre was cut to pieces or taken prisoner. The latter, fought against Rennenkampf's vastly superior Army of the Niemen, aimed at out-flanking his right and threatening his communications. A timely retreat foiled the stroke, but deteriorating into a rout, left Rennenkampf's Army incapable of action for some months.

The 10th Army Corps and the 42nd Division at the Battle of the Marne. By Lieut.-Colonel Lucas.—A clear and concise account of the events of the 6th and 7th September, 1914, as far as concerned the 5th Army (General Franchet d'Esperey) and the 42nd Division on the left of the 9th Army (General Foch). Much of the information is drawn from "La Batailles de la Marne," a recently published book by M. Hanotaux, and supplements the account of the action of the 42nd Division published in the *Revue* for 15th February, 1920.

Infantry in Open Warfare. The conclusion of the article by Commandant Padovani. Chapter II. continues the offensive action, dealing with special cases—open ground, close country—especially woods—night

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attacks and action with tanks. The remarks on the French theory of the employment of tanks are of interest. Chapter III. studies the defence, and ends with some remarks on the conduct of a retreat.

The Japanese Army. By Lucien Bec.—Commencing with a brief history of the modern army since the abolition of feudalism in 1868, the Japanese doctrines of war and the moral forces animating officers and men are studied in Part II. Part III. deals with organisation and Part IV. with the effect of the Washington Agreement on the Army. Briefly the infantry, cavalry, field artillery and engineers are being reduced, while mountain and heavy artillery, railway, telegraph and aviation units are being augmented.

Military Chronicle of Economic Questions. M. Pierre Bruneau this month provides an eulogistic dissertation on French military and civil aerial communication with and between the Motherland and Colonies in the Near and Far East and North Africa, and the use of aircraft for surveying and political missions.

(*November*, 1924.)—*What the Germans think of the French Artillery.* By F. de Castlenau, Artillery Squadron Commander.—The writer quotes extracts from recent publications by German Generals, which betray the extent to which French artillery development before and during the war occupied the attention of the German High Command. He advances arguments in explanation of French superiority in this arm, and closes with a hope that impending Army legislation will not alter an organisation which has achieved such notable and proved results.

Essay on the 4th Bureau of the Army General Staff. By Major S. Raoult, General Staff.—This article recounts the failure of the pre-war organization called the D.E.S. (*Direction des Etapes et des Services*), which worked under the General Staff, and its replacement by an actual branch of the Staff. This 4th Bureau consisted of three sections, to which were entrusted all arrangements for ordering and distributing munitions, engineer stores, provisions, medical and veterinary stores, transport of reserves, evacuation of casualties, salvage operations, pay and post offices, including the provision of new and the extension of old railway stations and maintenance of light railways and roads therefrom, in fact, all Army services, except aviation and signals. Of interest to students of French Army organization. (*To be continued.*)

A.R.R.

REVUE MILITAIRE SUISSE.

(1924. *Nos.* 10 *to* 12 *inclusive.*)

THE article by M. Jean Fleurier entitled *Une légende. La faillite de la fortification permanente pendant la grande guerre* is continued (No. 10); matters affecting the armament and garrison of Antwerp, and the operations of the Germans against the Belgian citadel are dealt with. M. Fleurier points out that the real weakness of Antwerp lay in the inadequacy of its artillery, and considers it astonishing that, having provided fortifications with a lavish hand, and even sacrificed solidity by reason of the profusion with which defence works were constructed,

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the Belgians should, in the circumstances, have neglected to pay adequate attention to the matter of maintaining the armament of the citadel up to the standard required by the continual advance in gunnery. He justly considers that fortifications, although designed primarily for the purpose of playing a defensive role, should at the same time be capable of a measure of offensive action : without suitable and sufficient artillery, the most costly defence works, he says, become nothing more than inert and useless buildings. The prevailing idea in Belgium being that the fortress of Antwerp was a *place of refuge*, it would seem that the successors of Brialmont lost sight of one of the most important of the essential needs of a fortified centre. When first planned in 1859, the proposed armament for the Citadel defences were, for the purposes of that time, both adequate in character and ample in number—*inter alia*—pieces of 12 and 15 centimetres being provided. In 1914, a large number of the guns mounted in the works, as well as those in the Artillery Park of the fortress, were of an obsolete type—details of the armament of Antwerp at the outbreak of the war are given in the original article. The ammunition available for the artillery was also insufficient ; at most, there were only 1,000 rounds per piece for the 15 cm. guns and 120 rounds per piece for the 12 cm. howitzers. The ammunition for the field pieces was also inadequate. Further, insufficient attention had been paid to matters affecting the fire tactics of the artillery ; no range tables had been prepared for some of the howitzers and there was only one observation balloon, and that was without the means for rapid communication with the guns. Again, no steps had been taken to organise a system of artillery observation posts in anticipation of a coming war. Among other defects and deficiencies to which M. Fleurier draws attention are the small number of machine-guns and the inadequacy of the supply of small arms ammunition in Antwerp ; in one Sector of the defence there were only nine sections of machine-guns for a trench line system 17 km. in extent. On October 2nd, during the Battle on the Néthe it was discovered that only 1,800,000 Mauser cartridges were available in the place, and four days later, when the retreat from the river began, in certain cases, the infantry ammunition supply was so reduced that only 30 rounds per man remained on hand. Commenting upon the character of the garrison of Antwerp, M. Fleurier points out that the Divisions of the Field Army which had been engaged with the enemy before retiring to the shelter of the fortress had suffered heavy casualties, particularly in officers. Arrangements did not exist in Belgium at the outbreak of war for replacing the casualties in the ranks of the officers ; this accounts for the deterioration of the offensive spirit of the infantry of the Field Army and the caution displayed in connection with the sorties made from Antwerp. Further, the fortress troops were distinctly poor in quality ; they were insufficiently trained and their *morale* was at a low ebb. That the Germans assumed a defensive attitude before Antwerp from August 20th to September 27th arose, M. Fleurier points out, from the fact that the German High Command very properly desired to utilise the bulk of the forces at its command for the purpose of crushing, if possible, the Franco-British Army ; in order thus to reach Paris in as short a time as possible. Once the Meuse was crossed the Belgian Army was, in German eyes, a negligeable quantity

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which could be dealt with at leisure. Moreover, an attack on Antwerp was rightly held to be a task of far greater magnitude than that of forcing the defences of Liège and Namur. The experiment of the *attaque brusquée* at Liège taught the Germans a serious lesson and brought home to them in practical fashion that such an operation was a very costly affair and that success was only to be purchased at a high premium; the Germans naturally did not wish to purchase a victory on the Scheldt at a price comparable to that paid by them on the Meuse, but preferred to obtain the discount which their super-cannons were capable of winning for them. However, at the outbreak of war, the Central Powers were not plentifully endowed with weapons of this kind, and as Maubeuge, among other French fortresses, had yet to be reduced, the demands on the German heavy artillery were then sufficiently exacting to necessitate a cautious advance against the defences of Belgium's Citadel. Finally, when the Germans did push their attack against Antwerp, no attempt was made properly to invest the fortress; the troops employed by them in that region consisted almost entirely of reserve units, and they allowed the Belgian Army to escape from them and to gain the Yser, thus depriving the Central Powers, to a great extent, of the fruits resulting from the capture of the Belgian stronghold.

W.A.J.O'M.

BULLETIN BELGE DES SCIENCES MILITAIRES.

(1924. *Nos. 7 to 9 inclusive.*)

THE account of the operations of the Belgian Army during the War of 1914-1918 is continued in Nos. 7 to 9 inclusive; therein the narrative of the events of October 5th in connection with the defence of the line of the Scheldt is concluded; the happenings in the area under General Clooten, *i.e.*, the area not yet penetrated by the Germans, are dealt with; the measures taken to establish a secondary base are described; the movements of the Anglo-French force sent to succour the Belgian Army, and the steps taken to secure the safety of the Channel route during its transport are detailed; and particulars are given of the progress of the German advance on October 6th (against the sub-sector held by the 1st Division). It is pointed out that the Germans were not at this time pushing their attack against the western defences of Antwerp with any vigour, because they were hampered by the existence of the waterways in that region and by the general situation. It is suggested also that, perhaps, the real reason why the Germans proceeded in a somewhat leisurely fashion with their siege operations was because they felt certain that the Belgian Field Army would never leave the shelter of the defences of their famous stronghold, and the convictions of the German High Command in this matter were strengthened by the knowledge that British reinforcements had been pushed into Antwerp. The Germans may well have argued that it was not at all likely that the British military authorities would have made special efforts to reinforce the garrison of the fortress had not a decision been arrived at to put up a

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defence *à toute outrance*. In the circumstances, the much criticised move of the ill-equipped units of the R.N.D. into the beleaguered city seems to have served a useful purpose; the Germans were completely deceived by the measures taken, and possibly it was this fact that made it possible for King Albert to withdraw the bulk of the Belgian Field Army from the doomed city without any serious molestation on the part of the enemy. A secondary base had, since October 4th, been established at Ostend and Zeebrugge; in view of the possibility of damage being done to the railways by raiding parties, working parties and a couple of trains loaded with the materials necessary for effecting rapid repairs thereto were constantly held in readiness at Ghent to proceed at a moment's notice to any spot designated by the General Staff. The Belgians were able to maintain a railway service, in spite of many serious difficulties, between the coast and Antwerp; fortunately, the Germans took no steps to damage the line, the only one available for the purpose, which was being used. The Belgian High Command, it is made evident, was bitterly disappointed with the measures taken for reinforcing the Belgian Army; of the reinforcements promised, only the three British Naval Brigades joined the Belgians in time to take part in the defence of their citadel. By October 6th the troops of the Belgian 5th Division had reached the limit of their resisting power and began to retire. The Naval Brigade under General Paris, however, was still holding out in its position north of Lierre, and, owing largely to this circumstance, the Belgian 1st Division also continued to occupy its defensive line for a short time longer. During the afternoon the Germans made a serious breach in a part of the main line in No. 3 Sector of Defence, and, in consequence, orders reached the Belgian 1st Division at 5.30 p.m., directing it to retire towards Hemixem. Just when orders for this move had been issued, fresh instructions reached the Divisional Commander directing him to retire to Aertselaer, and to take steps to cross to the left bank of the Scheldt by the bridge at Hemixem. In the meantime, in view of the fact that the chances of the Belgians regaining the line of the Nethe near Lierre seemed hopeless, King Albert summoned a final meeting of the *Conseil de Défense Nationale*. A decision was now arrived at to move the bulk of the Belgian Field Army to the left bank of the Scheldt, and the further defence of the fortress was entrusted to the Belgian 2nd Division, the 2nd Brigade Mixte, the brigades of the R.N.D. and the permanent garrison consisting of fortress troops.

The article by Baron W. de Heusch entitled *L'Enveloppement à la Guerre* is concluded in No. 7. The German enveloping movement in the Great War, 1914-1918, is dealt with, and the excuses given by the Germans for its failure recorded. Baron de Heusch points out that an enveloping movement cannot in the altered circumstances of warfare, where very large masses of troops are employed and the latest developments of science, such as improved optical apparatus, aviation and wireless telegraphy, called in aid, be carried out with that measure of secrecy which is essential for effecting the surprise of an adversary; consequently, the chances of success of such a manœuvre are to-day at a serious discount. As soon as an opponent discovers an enveloping movement, and this is likely to occur the moment it is put into operation,

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he will assuredly at once adopt tactical dispositions to meet the situation, and thus bring about a failure of his enemy's enterprise.

The article by Major B. E. M. de Grox, entitled *Le Terrain et la Guerre* is continued in Nos. 7, 8 and 9. In some quarters the view is held that nowadays the character of the *terrain* on which the collision of *national armies* takes place matters little. Major de Grox shows in his article that such a view is mischievous, and that, on the contrary, a comprehensive study of the features of the *terrain* of a future theatre of operations and the adaptations of the strategical plans thereto are, if anything, of greater importance than of yore ; extracts from many important publications are given to show the importance in which the *terrain* has been held in olden times.

Among other articles of interest in the numbers under notice are :—*Quelques considerations sur les couverts* (Nos. 7 and 8) ; *La defensive de retraite* (No. 9) ; and *Reflexions à propos de la 5e arme* (No. 9).

MILITÄR WOCHENBLATT.

(*10th January*, 1924).—In this issue is an interesting review of a brochure on march dispositions as affected by the air arm, written by Hauptmann Waldemar Pfeiffer, and based on his, apparently, extensive war experiences. The book deals with the question of the extent to which marches in closed up columns on roads are possible, particularly by day, when opposed to a superior hostile air force, and according to the critic incites not only the higher and " middle " leaders, but even the subordinate leaders, to serious thought, which leads to new, unusual and, perhaps, disturbing views. As the offensive capabilities of the hostile airmen must be taken into consideration much more seriously than formerly, especially in view of an insufficient anti-aircraft defence, the consequence, according to the author, will be that through the increase of their vehicles (first line transport and train) troops have become extraordinarily vulnerable to air attack and will only dare to carry out operation marches by night ; further, that it will be found desirable to continue these marches by night up to the point of gaining touch, whilst the reconnaissance and establishment of routes will follow in the day time. But where it is necessary to go from night to day marches and tactical touch must be got not only by reconnoitring detachments, but by the infantry division itself by day, it will then be necessary for the division to deploy at dawn and only to advance deployed. This means that not only will the troops have, out of all proportion, far more taken out of them than formerly, but also certain units will always be more held up by physical obstacles than others. The author deduces from this the necessity of reviving the old " lines of demarcation," that is to say, to lay down fixed lines on the ground up to which for the time being the advance is to go and beyond which further advance is only to be made on receipt of specific orders, after connection laterally and in depth has been established. Advances of this nature, deployed and piece-meal fashion, will, of course, restrict appreciably the rate of marching, so that two kilometres an hour may well prove an absolute maximum.

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The author has also something to say about the distribution of transport vehicles in the deployment, so that they shall offer the least target to hostile aircraft.

E.G.W.

HEERESTECHNIK.

(October, November and December 1924, *Numbers).*

THE " official " articles in *Heerestechnik* are getting fewer in number as time goes on. In the three numbers under review there is one official article apiece.

In *October*, caterpillar traction is described with special reference to tanks. A few interesting general statements are made, such as the fact that the pressure per square foot on the ground in the case of a German brand of caterpillar (weight 3,000 Kg.) is only $\frac{1}{8}$th of that under the hoof of a walking horse. The American " Christie " system, which allows of the use of eight indiarubber tyred wheels (28 Km. an hour on a road), or alternatively of an added caterpillar arrangement (14 Km. across country), comes in for notice, as does the French " Kegresse." In America it is the field gun, with its constant cross-country journeys, which is thought most suitable for such traction, and experiments have been made with caterpillar gun carriages. The inevitable drawbacks are classified as three in number :—

1. The exposure of the motor to possible damage.
2. The necessity for using the motor in making big switches.
3. The weight.

Very large guns and howitzers are to be caterpillar drawn (in order to get them off the railway). The writer then describes tanks and begins with a tactical discourse. He quotes the destroyer tank, tank of the line, and torpedo tank, which we have heard talked of in England. The classification preferred by the author is small, medium and heavy. The nine principal desiderata of a tank are tabulated and end off with desirability of floating. (A screw is mentioned as a proved method of tank propulsion in water.) There is a chance of some small low tank in which one man (lying) shall control the motor, steer, work the machine gun and keep touch with his neighbours! The French types, Renault, Schneider, St. Chamond, are briefly described and also illustrated. English, American and Italian types follow. In describing anti-tank measures the relatively poor practice of tank gunners is insisted on. Great emphasis is laid on the identification of type (and hence choice of counter-measures). The use of obstacles is to shepherd tanks into definite avenues of approach. Mine fields are useless because the tank exerts less pressure than a man's foot and the remedy is more dangerous than the disease. The heavy anti-tank rifle will deal with light fast moving craft, the infantry gun or light trench mortar with mediums—but the field gun is the best answer for all. (Armoured aeroplanes are mentioned as likely to be valuable in this connection).

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Captain Justrow writes in the November number on ballistics. He quotes an Inspector General of French Artillery on the ranges desirable for certain calibres. Here they are :—

		Metres.
7.5 c.m.	Field gun	14,000
10.5	How.	12,000
10.5	Gun	16,000
15.5	Gun	25,000
15.5	How.	14,000
24	Gun	40,000
24	How.	16,000

But German guns anyhow don't do it. Why? The muzzle energy is used up partly in the weight of the projectile, partly in the initial velocity. Not enough attention is paid to the former. The Frenchman's ideal is attainable if the weights of gun and carriage necessary for it are tactically allowable. Tables and graphs are given. I feel sure the article is sound and informing and leave it to our friends of the Regiment.

In the December number is an article on the industrial country and national defence, by Major A. D. Drees. England and the highly industrialised France, Italy and Germany are contrasted with America and Russia. We have the engineering, scientific and administrative problems of modern war to the credit of the industrial state. Food, men and horses on the other side. The increasing value of an organised industry on the " home front " is gone into with, one would think, unnecessary thoroughness. It jumps to the eye. The American Civil War is quoted as the first striking illustration of the strength of a mobilised industry in spite of the simplicity of contemporary equipment and armament. In the future it is to be looked for that an industrial state will supply enormous stocks of tabloid foods! As regards horses, the author thinks them too large, too hungry, and too " expendable." The machine must do their work. He is interesting on the man question. The industrial worker, quick to understand modern machinery and weapons, is also physically on the whole better and not worse than his country cousin. He quickly takes the healthy tan of exposure and his capacity for prolonged physical exertion is just as great. Here the value of games is underlined, and Germany congratulated on the way it has taken to Anglo-Saxon pastimes. But the food problem is also most important. The United States are quoted as combining the advantages of industry and agriculture and Russia described as having the resources, but being unable to profit from them because of the political regime. The romance of war is, then, killed by industry and we shall all be " mechanicalized," but in the author's opinion we need not be down-hearted and are promised more " frisch-fröhliches soldatenleben."

There runs through the three numbers under review an article, on the use of engineers (or pioneers) in war, by Captain (on the Staff) Dr. Oskar Regele of the old Austrian Army. He believes first of all that every formation should have its own pioneer units and that regimental pioneers (sog. " Truppenpioniere ") are of little use. To-day and to-morrow it is only the real tradesman who can deal with the problems which arise. Here is his proposed organisation anglicized :—

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G. H Q.

Chief Engineer.

Reserve units of various sorts such as bridging trains, inland Water transport, etc

1st Army H. Q.

Chief Engineer 1st Army.

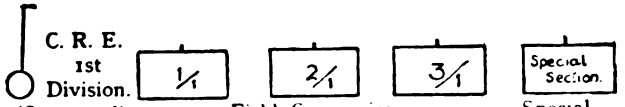
R. E. Park. Mech Trans. Special Reserves, Works Cos. etc.

2nd Corps H. Q.

Chief Engineer 2nd Corps.

R. E. Park. Mech. Trans. Special Reserves, Works Cos. etc.

1st Divisional H. Q.



C. R. E. 1st Division. (Commanding 1st Battalion.)

Field Companies.

Special Section.

1st line transport. R E Park. Mechanical Transport.

1st Inf. Brigade.

2nd Inf Brigade.

1st Infantry Regiment. 2nd Infantry Regiment. 3rd Infantry Regiment 4th Infantry Regiment.

Field Companies

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This organisation gives seven Companies to the Division, 14 to the Corps (with the reserve Corps, 28). In peace, electrical, mechanical, " flammenwerfer," gas and other companies, are represented by cadres. Bridging trains are " scratch " units on mobilisation and engineer troops and bicycle companies accompany cavalry and cycle battalions (to which, judging from current literature, the Austrians have a leaning). It is considered most important to safeguard the command and organisation of all technical work to the C.R.E., the tactical command to the G.O.C. formation, but he leaves the C.R.E. of a Division, in a Corps, between the devil and the deep sea. Divisional engineers may be used to reinforce other divisions on occasion, such as river crossing, etc. It is of importance to arrange alternate spells of front line and rear line duty. (It is not apparent if the author anticipates exchange of divisional units in this connection). Losses should be avoided and pioneers seldom used as infantry. Casualties will be frequent in open warfare, exceptional in a war of position. In battle every formation deficient in pioneers will suffer unnecessary loss in men, fighting energy, and time.

Pioneers in the Attack.—Every attack requires engineer preparation, including :—

(*a*) A technical study of the sector.

(*b*) A combined reconnaissance with staff and other arms.

(*c*) Proper distribution of pioneer units and the concentration of personnel and stores.

Officers must be properly equipped with maps and knowledge of all matters of import in the theatre of operations (R.E. Intelligence). The importance of a combined reconnaissance is heavily underlined. The preparation for attack includes communications (covered), traffic directions, roads, bridges (for tanks especially), splinter proofing dumps etc. Pioneers must rehearse the attack with infantry, and this is particularly important in river crossings. Engineer stores are a most important item of preparation. Every formation should have a certain number of pioneer officers for reconnaissance and " odd jobs " to prevent robbing units. Attacking tanks must have their attendant pioneers (also in Tanks ?) to clear the way. It is only by good organisation and peculiar effort that the artillery can be helped forward in time to exploit success to the full. After a successful attack the roads for supply are the main task. Better one good road than many bad. A river crossing calls for particular pioneer effort and lightly equipped units must be ready to help on the pursuing infantry (infantry bridges, etc.). The pioneer's task in attack is to clear the way for the rest, always to be helpful and on the spot, and to overcome those natural and topographical obstacles which are often the worst.

In the Defence.—If the defence follows on an advance it will be long before all pioneers are up. Communications are always the most important task and it is useless to indulge in other activities till they are put right. Working parties must be asked for. This being done, field fortification, artillery positions and O.Ps., strengthening bridges for heavy guns, camouflage, etc., follow. Mining is a last resort when all

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other means fail or counter-mining is necessary—for of all occupations it calls for the greatest and most exhausting efforts. For the defence of rivers and bridgeheads water mines are most important. The maintenance of communications during defence makes a continuous pioneer reconnaissance necessary. In retreat drastic demolitions must precede the withdrawal of units. They should then be hurried to the next line of resistance for its preparation. Rearguards have their own pioneers.

Lines of Communication.—Two remarks of interest are :—

(*a*) The necessity for uncommonly efficient and energetic officers for R.E. stores and parks (owing to the vast importance of supply) ;

(*b*) The necessity for running inland water transport with pioneer staffs.

In giving this article from Austrian sources, the Editor states that he does not thereby endorse the views expressed, but hopes to provoke discussion.

An article of some interest to the student of Ballistics appears in the October number in the form of an answer to Vahlon, the author of a recent book on ballistics, by Dr. Ing. Becker. Becker had reviewed his book, and these two experts are ventilating their respective views.

In the October and November numbers, Major Buhle gives a good summary of the factors affecting heavy draft. The articles are full of statistics dealing with the horse, harness, surface, gradient and pace. Major Buhle is evidently a horse lover and a good horsemaster, and his articles will be useful to many.

An article on anti-aircraft gunnery by Walther describes two methods of estimating the forward angle. One, depending upon the measurement of the angular velocity of the target, finds the forward angle as a function of this angular velocity and the time of flight of the projectile. The other fixes positions on the target's path, the point on this path where the projectile would arrive, and so calculates the forward angle. For the first an electrical measurement is obviously ideal but suffers from the inevitable jerkiness with which the observer follows the movement of the plane. There are many equations and a few diagrams, and the article is not easy reading.

In the December number Karl Lüdeman gives his ideas on a general service theodolite. He wants to combine the instrument for topographical, railway and artillery surveyors but, rightly, excludes from the scope of this combination any instrument wanted for ruling triangulation. We are interested in the same problem, which is a very difficult one in times when so many far-reaching alterations and novelties are being brought out. Lüdeman suggests combining theodolite and alidade as a possibility—a terrible thought, A "bonza" outfit instrument of this sort would please none but the Ordnance Officer.

H.St.J.L.W.

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MILITARWISSENSCHAFTLICHE UND TECHNISCHE MITTEILLUNGEN.

(July-August and September-October numbers.)

Major Franz Stuckheil writes of the offensive period in the history of the Defence of Przemysl during its second investment. Like the previous article this is interesting reading and a clear and concise narrative, but no claim is made as to its accuracy in detail, and the information is mainly second-hand. This part of the second investment (November and December, 1914) contains only one effort on the Russian part to take a portion of the defences by storm. The investing troops of value were drawn off in succession to the Carpathian front, and the garrison made a compulsory number of sorties in the attempt to delay these movements and to get identifications. On the 11th, 14th, 16th and 20th November sorties were made; on the 14th, 15 battalions and 8 batteries took part. Successful in fixing the enemy temporarily, and at small cost, the sorties never succeeded in penetrating the main Russian line. On the 28th the Russians made their solitary move and succeeded in establishing themselves in close proximity to a portion of the main line of defence. A counter-attack on the 30th of November accomplished little. In December sorties took a more serious form. On the 8th December the garrison was warned of an impending attack by the Austrian 3rd Army, and asked to co-operate. A force of 19¾ battalions and 15 batteries was told off for the effort and on the 9th and 10th it took place. At a cost of 700-800 casualties the main Russian line was reached, but not broken. On the 13th and 14th came the news of the battle of Limanowa and hopes ran high of almost immediate relief. To meet the advancing Austrian 3rd Army and to cut the Russian line of retreat a sortie was arranged for the 14th. The article breaks off here and will, no doubt, be continued.

Two interesting articles describe the surprise attack by the Roumanians on the Austrian 61st Landsturm Infantry Division at Agasu in the valley of the Trotus. This action, which appears to reflect credit on most of those concerned on both sides, took place on the 17th October, 1916. Charged with the defence of a position with forces insufficient for the purpose, General Boian of the Roumanian Army, decided on a bold turning movement against the advancing Austrian Division and nearly brought it off. The action is described in successive articles from the Austrian and Roumanian points of view, and by participators on either side. A 21-mile march over mountain and forest preceded the attack.

In an article on the German Army of the East in the summer of 1914, Lt.-Colonel Kiszling asks whether the Germans fulfilled their pledges to the Austrians or not. He concludes not. The agreement was that the Austrians were to guard the German rear for six weeks—which was done. The end of that period found the Austrians in serious plight, with threatened flanks, forced to break off the battle of Lemberg and scuttle for safety behind the San.

A definite understanding had been arrived at that the Germans were to fall on from the north at the end of the six weeks, even though v. Moltke, in 1909, had clearly foreseen the difficulties involved. But

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the Germans had their eye upon the defence of East Prussia. After Tannenberg (end of August) the way to the promised German advance south was open. Instead, however, Hindenberg went for Rennenkampf (Masurian Lakes 7-14th September). The chance of ensuring an Austrian victory over the main Russian forces had now passed, and although German victories had been won, the original agreement had been definitely broken and a great opportunity lost.

In the July-August number, Fritz Heigl gives his third article on Camouflage. He finishes off the camouflage of individual objects with some remarks on O.P.'s and then describes Painting Camouflage under the three headings :—

A. Painting to represent three dimensional objects.
B. Painting in smallish stipple.
C. Painting in large stipple or stripe (" Jazz " painting.)

After pointing out how, in case *A*, one must copy local nature or art, he describes a bad case—(German Aerodrome). As regards *B*, whose object is to sink the object into the background, he quotes the Spithead Forts. Colour is not so important to the neutral effect as the patchwork design. Under heading *C* the aim is to deceive, not the eye, but the understanding. Jazz painted ships and tanks are described. Photographs illustrate the article.

The failure to exploit the Austro-German victory of 1917 in Venetia by pushing on beyond the Piave is discussed by Dr. Oskar Regele. The pontoon and bridging trains were not available when and where they were wanted. Teams had been handed over for artillery and supply work. Such scratch teams as were got together foundered almost at once. The magnitude of the operation had, indeed, been allowed for in the demands from the Pioneers on the spot, but these demands were not complied with.

Successive articles deal with the armament of the Artilleries of Europe and the United States. The state of each before the war is contrasted with its present position. The main item of interest is in the description of the measures which have been taken in America to design the types of ordnance advocated by General Winterveldt's commission after its studies in England, France and Italy.

Major Rendalic continues his digest of the infantry tactics of the attack. This number talks of the assault and break-through. Austrian, German, French and English ideas are compared. The tactics of the forward movement through the zone of resistance are most important to think out and to practice, but in fact this is seldom done. Manœuvre and training generally stop at the assault. The difficulty of stage-managing further " in-fighting " prevents practice, which is none the less essential, for here, if anywhere, the group and section must fight forward on an intelligent model. Our tactics are considered too complicated, and the brigading of machine guns too likely to rob the battalion of its proper fire support.

Italian light and heavy tanks are described in the September-October number with good illustrations.

Colonel Franz Andarle contrasts Radio-telegraphy with Radio-telephony. The former, illustrated by a 5 watt (antennæ) emitting set,

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with an 8 metre mast, and a working radius of 50 k.m., allows of the installation of one set every 500 metres. If calculated for an area of 4 k.m. side, 98 stations can be in use simultaneously. This calculation is based on tuning to wave lengths separated by 1½ per cent. But a radius of action of 50 k.m. may be considered much too high, and by reducing it suitably one might put 196 stations in the same sized area.

With Radio-telephony, however, a much greater percentage must be allowed between wave lengths and much greater power. The 4 k.m. side square will now hold only five stations.

As an illustration of " concentration camouflage " in connection with the series of articles on Camouflage now appearing, Colonel Schwarzleitner instances the measures taken to disguise the actual point at which the German troops were to operate in the 1917 offensive against Italy.

Major Erhard Raus describes the activities of a cyclist battalion at the Col de Lana.

Several books of obvious interest are reviewed, amongst them

Geheime Machte. Nicolai. Leipzig, 1924. (Espionage and contre Espionage.)

Die deutsche Wehrmacht in Wort u : Bild. Schwarte Offene Worte, Berlin, Charlottenburg, 1924.

Generaloberst Arz." Rikola Verlag Wien, 1924. (A record of the War Work of the last Austrian Chief of the Staff).

(*November-December Number*).—Field Marshal Conrad is in the process of writing " My Service years from 1906-1918." (Aus meiner dienst zeit, 1906-1918.) Four volumes have appeared, and the last includes the Battle of the Marne, that of Lemberg, and the Austrian retreat behind the San. A review of these four volumes opens the November-December number.

An interesting article on company training starts by saying that in war one company does not fight little battles all to itself either on reconnaissance or protective duties. Training must aim then at a real picture of the preparation for either attack or defence, and the gradual development of the situation. In fact, the same scheme should last many days, an actual (not hypothetical) enemy (also training) must be provided, and the gaps (if any) between situations must be lectured about.

The general idea is illustrated by an exercise in daily parts—which are—1. A defensive position and a sector of that position—its occupation and preparation. 2. A forward company—its position, defence, manning, etc. 3. The enemy's approach—till touch is established, lecture only. 4. Practical again—the deployment and advance of a company of the enemy towards the position of 2. 5 and 6. The attack up to 400 yards from 2. 7 and 8. Close fighting into the battle zone. 9. A partially successful counter attack leaving some elements still in the position. 10. Reserves thrown in, and a final successful attack.

Tv e ity-seven pages and accompanying diagrams work out the various situations—which repay study.

Tanks absorb a lot of room in German and Austrian military journals. In this journal British, German and Italian tanks have been described already. Now it is France's turn, and D. Ing Fritz Heigl gives a long

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description of all French types, except the Char 2 C, which will follow in a later number. There is little tactical detail, but armament, armouring and engines are carefully described.

Colonel a. D. Ing. Wilhelm Junck describes the substitutes and makeshifts used in Austrian munitions during the war. It would seem that a great deal of Austrian ammunition of this kind is still in existence—principally, no doubt, in the countries of the Little Entente—and the question is one, therefore, of interest to us all. Fuzes, propellants, shell and cartridge cases, driving bands, etc., were all experimented on. A curious point, and one dealt with pretty thoroughly in this article, is the effect of using iron shrapnel bullets in place of lead. Iron bullets to come up to the required weight per bullet are larger than lead, and in addition do not pack so well. They had to be used, however, and consequently the weight of the projectile had to be altered, and there followed an alteration in the range. This is only one example of how each makeshift altered every dependent factor, but it is of value to have a description of these makeshifts on record.

L. (he might give his full name, for he has lots to say) writes on the place of the Air Arm in the state. Difficulties will occur in the use of flying units where the personnel does not actually belong to, and interchange with, that of the service it serves. For all that, the balance of opinion is in favour of a definite Air Arm. But there are grave difficulties. Given half a chance, each service will arrogate to itself the principal role. Moreover, every operation undertaken separately by one service requires the aid of the others. Quite temporarily, and in peace particularly, the solution may be found in raising marines for the Navy, or in attaching Army units to the Air Force (Iraq is quoted). But such a procedure is bound to be ephemeral, and the exchange of such units—their relief when wanted, etc.—is impossible in the limited time which emergencies offer. The only way, indeed, is to have some central and directing staff which may use all its resources without being answered back. Especially must this be so in national defence (again we are quoted) in view of the quicker development of danger due to flying. In peace, cabinet decisions and political direction may answer. In war they never could, and the common high command and staff becomes inevitable—otherwise we fall into the troubles common to divided councils and coalitions without a head. It is pleasant to see ourselves described as "conservative in form, open-minded in fact," and it will be very interesting to see if anyone else wishes to break a lance with L.

H.St.G.L.W.

VOINA I MIR.

No. 15.—An article entitled "Verdun—place of destiny for Germany and France in the World War," by General von François, who held a high command during the attack, is of considerable interest. Verdun was the centre of the strategic and tactical plans of the two nations, and the battles fought there afford an abundant source from which instruction can be drawn, not only in matters of the higher direction, but in the finest details of the tactical conduct of position warfare.

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The five German armies began their advance into France on August 18th, preceded by two cavalry corps. The left flank of the advancing group of German armies approached the northern edge of the fortified periphery of Verdun, which became the axis of their great strategical turning movement. The further the turning movement progressed, the greater became its danger to the German communications. A strong French counter-attack from Verdun would immediately react on the life-giving arteries of five German armies and might stop the whole advance.

The possession of Verdun, which was not in a condition of complete preparedness, was, therefore, of great importance, but the German Crown Prince, commanding the 5th Army, had not sufficient means at his disposal for an attack, and was, therefore, obliged to modify his efforts to carry out the order of August 28th from G.H.Q., which said: "The 5th Army will advance to the line Châlons-Vitry en François. This army must by refusing its left cover the flank of the wheeling armies until the 6th Army can take this responsibility on itself west of the Meuse. Verdun must be bottled up."

This Army remained for long held up before Verdun. The encirclement of the fortress was accompanied by the fiercest fighting. The night attack of September 10th led to a grip being obtained on the fortress from the north. The fate of Verdun hung on a hair, it only remained to occupy St. Mihiel on the South.

At this point Colonel Hentsch was sent by Moltke to visit the armies to take stock of the position. He visited the Crown Prince's headquarters on September 8th, but the latter tried to get rid of him as soon as possible. On September 11th Moltke himself visited the Crown Prince; he was already a broken man, and his outlook was pessimistic. An explanation took place between them. The Crown Prince expostulated against a hasty retreat and was allowed to withdraw his troops in good order on September 12th and 13th. Verdun again breathed freely.

When the enfeebled von Moltke was replaced by General von Falkenhayn, the latter succeeded in establishing equilibrium on the western front. The Crown Prince's army was again moved against the northern front of the fortress and severe fighting began. On the eastern bank of the Meuse, south of Verdun, the fort of the Camp des Romains at St. Mihiel was taken by the Bavarians.

In the middle of October, 1914, the Crown Prince received the order to capture Verdun by means of an accelerated attack, but his demands in troops, artillery and stores to effect this end were so great that the attack was postponed. At Christmas, 1915, the High Command was again bent on the idea of attacking Verdun.

The Crown Prince, correctly appreciating the situation, asked for permission to attack on both banks of the Meuse, but it was decided by the High Command to limit the attack to the east bank. This was a half-hearted plan, which indicated an under-estimate of the enemy resistance.

On February 21st, 1916, the attack began in bright winter weather. By the 24th the advanced defensive system of the French on the eastern

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bank of the Meuse had been broken through, and German guns were able to shell the outer belt of forts and the fortress itself. Verdun would have been taken if fresh troops had been poured into the fighting lines to continue the attack. The High Command promised them to the Crown Prince, but they never arrived. The French gained time to bring up reinforcements and the attack hung fire. The Crown Prince renewed his proposal to carry out an attack on the west bank of the Meuse. He insistently begged permission to take the height, "Le Mort Homme" and the crest adjoining it, so that he might from it stop the very effective flanking fire of the French on the east bank. This time the High Command consented. On March 6th the attack on the west bank began in a heavy snow storm. By March 14th the 6th Reserve Corps had reached the foot of the northern slope of "Le Mort Homme." The French resistance stiffened, and the Germans advanced but slowly.

At first the attack on both banks was carried out under one direction, but there was a distinct improvement in the conduct of affairs when at the end of March the Crown Prince divided the fighting area into two sectors, handing over the eastern sector to General Müder and the western to General von Gallwitz.

On April 9th the 22nd Reserve Corps, under the command of General von Falkenhayn, brother of the Chief of Staff, captured a part of "Le Mort Homme;" on May 8th the 4th Infantry Division occupied height 304. Strong French counter-attacks met with some success. The possession of these two heights became more and more a question of national honour, and the daily papers in France and Germany expressed a keen interest in them. By the end of May, 1916, the objective on the western bank had been attained. The troops were in need of rest. The 6th Corps was replaced by the 24th Reserve Corps and the 22nd Reserve Corps by troops of the 7th Army Corps commanded by General von François. On June 8th, 1916, he reported to the Commander of the western attack, General von Gallwitz, the arrival of his troops. He inquired about artillery resources and was told that the staff of the Army would direct artillery operations. This was by no means reassuring, since it rendered close co-operation between infantry and artillery doubtful.

His first care was to ascertain by means of aeroplane reconnaissance the exact line to which the advance had reached: the deduction was that possession of Le Mort Homme was by no means complete. The French counter-attack of June 15th recaptured a considerable part of the position from the 56th Infantry Division, which the latter did not succeed in re-taking. General von François gave the command on Le Mort Homme to the far-seeing and energetic commander of the 55th Infantry Regiment, Colonel von Feldman. The French were very active on Le Mort Homme. Attacks followed one another daily, but none of them was successful. According to plan, it was proposed to pass from passive defence to renewed attack. The changes in command which ensued after July 17th put the command of the western attack in the hands of General von François.

On the right flank of his force was the 2nd Wurtemburg Landwehr Division, east of it was the 24th Reserve Corps, composed of the 54th and 38th and 192nd Infantry Divisions. The 7th Army Corps formed

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the left flank, resting on the Meuse. On Le Mort Homme the 13th Infantry Division had replaced the 56th Infantry Division. Before point 304 was the 38th Division, which had already three times vainly tried to capture the height.

Owing to lack of munitions, attacks could not be undertaken on a large scale. The method adopted was one of sudden blows and modest objectives; for example, a short bombardment by artillery and mine throwers, which drove the enemy garrison into their dugouts, followed by infantry storming parties.

Behind the front was established a practice school for the attack of trenches, equipped exactly like those destined for attack; every man had to know his task. This method proved very useful. In the twenty-four major and minor contests which ensued the troops of the Western Meuse force gradually occupied the enemy positions with comparatively trifling losses.

At the beginning of July, 1917, Le Mort Homme and point 304 were completely captured. More than one interruption in the continuity of the operations took place owing to the despatch of divisions to other parts. In their place exhausted divisions were sent, which had to be hardened in a moral and physical sense before they could be used.

The differences of opinion between the Crown Prince and his Chief of Staff, von Knobelsdorff, respecting the further conduct of the attack, had a paralysing effect on the forward movements. Since August, 1916, the Crown Prince had been convinced of the uselessness of the attack and wanted to stop the advance. But General von Knobelsdorff considered the continuation of the attack on the eastern bank essential for tactical reasons.

Finally, General von Knobelsdorff was replaced by General von Luttwitz. At the end of August, 1916, further changes followed which had a decisive effect on the position before Verdun. General von Hindenburg replaced General von Falkenhayn, and the Crown Prince took over the group of armies, retaining command of the 5th Army. The attack on Verdun was stopped, but General von François had to continue his operations with limited objectives. There was no doubt that the cessation of operations on the eastern bank would adversely affect the situation of the western bank. The activity of the French increased, the power of their counter-attacks grew, and the supremacy on the eastern bank passed more and more into their hands. Their first important success was gained on October 24th, 1917; they penetrated to a depth of 2-3 kilometres and a considerable number of prisoners and guns was taken.

The enormous work which the Crown Prince's position involved led to the command of the 5th Army being handed over to General von Lochov, but after the defeat following on the French attack of December 15th, that meritorious general was retired to a well-earned rest and the command passed to General von Gallwitz.

"In opposition to our serious setbacks on the east bank," says the Crown Prince in his memoirs, "our activity on the west bank always rewarded us. Frequent, carefully extended, aggressive enterprises of small scope brought comforting results."

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The complete possession of " Le Mort Homme " and point 304 was a signal success, but movement across the extensive plateau of Le Mort Homme could only be carried out with difficulty and immense losses. It was, therefore, decided to construct ways of communication below ground. Work was at once started by Reserve Lt. Lange, Leader of a section of electricians, a devoted and energetic man, and in a comparatively short time two tunnels were driven, which were a model of skill. One, which was 903 metres long, passed through the hill of Ravens Wood. Inside the tunnels were road material, habitations, tools, sanitary points, kitchens, stores, wagon sheds and even a soda water factory.

By the end of July, 1917, a considerable area on the eastern bank had been won back by the French. At the beginning of August the French threatened the General's left flank, and the whole area south of Forges Stream had to be evacuated. There arose a question about Le Mort Homme and point 304, monuments of German heroism. The general situation demanded that a position should be taken up on the north bank of the Forges Stream. Twice reports to that effect were made and were supported by the Crown Prince, but for reasons of *morale* on neither occasion did the High Command approve.

It was well known that the French were preparing a strong attack on the position on the west bank and measures had been taken for offering an energetic resistance. In the first line were disposed, from right to left :

2nd Wurtemburg Landwehr division—opposite Avocourt.
206th Division—east of Avocourt.
213th Division—on point 304.
6th Reserve Division—on Le Mort Homme.

Behind the line there were the 29th Division and the 48th Reserve Division.

The defence of point 304 was not easy ; there was a single trench along the narrow crest from which a communication trench led down the slope exposed to enemy fire. In spite of this, General von François believed in success, for there stood the hardened troops of the 213th Division. The General also thought hopefully of the defence of Le Mort Homme. The flat surface of this hill-top, where there was a strongly developed system of trenches with tunnelled communications, gave the defence great advantages. The troops there were brave and of an excellent type. They had lately arrived from the Russian front, where they had fought with conspicuous success, but they had not yet become accustomed to the conditions of warfare on the French front.

On August 12th, 1917, French artillery fire began against the front. A bombardment of observed enemy batteries was ordered with shells filled with yellow, green and blue cross gases. For 24 hours the action of the gases made itself felt, and then fire was started at other points. Under cover of patrols and small striking detachments the French front line troops were reinforced by fresh units. The French shattering fire increased from day to day ; our barrage fire no longer frightened them. From his observation post the General could observe the whole battlefield. Le Mort Homme and point 304 were like fire-breathing volcanoes. They were wrapped in thick clouds of smoke and vapour, which were uninterruptedly pierced by the flashes of bursting charges. Heavy

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bombs were falling in rear, bridges over the Forges were turned into splinters, and in its valley the poisonous fumes from the French gas bombs settled down. Nineteen balloons were hanging over the enemy position and directed the fire of his artillery. Squadrons of twenty or more aeroplanes cut through the air as far as Staray and cast their bombs there.

The shattering fire lasted for eight days, and in the early hours of August 20th an infantry attack began on the whole French front. Le Mort Homme was lost and a counter-attack delivered by the 48th Reserve Division failed. After the loss of this point the retention of point 304 was useless, and with the consent of the Crown Prince it was evacuated. During the night of August 22nd the brave 213th Division evacuated the position unnoticed by the enemy. Only on August 24th did the French renew the attack and move with all precautions on to the hill which had been evacuated three days before.

On the new position north of the Forges Stream the 206th, 213th and 6th Reserve Divisions were replaced by the newly arrived 54th Reserve, 15th Bavarian and 30th Divisions.

The French lapsed into inactivity. On Le Mort Homme and in Ravens Wood they behaved with such timidity that the 30th Division succeeded, in a series of nocturnal raids, in saving the guns which had been abandoned south of Forges Stream, eleven of which were quite fit for use.

Le Mort Homme and point 304 remained in the hands of the French. Verdun, the corner-stone of the French fortified system held out against the German storm. Verdun proved to be the saviour of France.

A.H.B.

THE MILITARY ENGINEER.

(*September-October*, 1924.)

Our Sister Service in England.—Major Gillette recently vacated the post of Assistant Military Attaché in London. In this article he gives a brief account of the history, achievements, and present-day activities of our Corps.

Doctrine of Permanent Fortification.—Lt.-General Schwarz, ex-Director General, Russian Corps of Engineers, discusses the development of permanent fortification in recent years. His views may be summarised as follows :—

1. All the artillery of the defence, which constitutes the essential element of such defence, and which includes everything from field guns up to the heaviest modern guns, should be organised as movable artillery and should have splinter-proof shields. During the siege, this artillery would fight in the same way as did the artilleries of the field armies during the last war, when they were on the defensive. All the peace time preparations for this artillery, as far as it is connected with the defence of fortified regions, should consist of the organisation of a network of roads for manœuvring, of firing positions covered against observation, of a network of observation posts for the observation of the results of the fire, and of a network of communications.

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Fixed turrets and emplacements may be used in very exceptional circumstances.

2. The fortified zone proper should have a considerable depth. All the effort of peace time preparation should tend, besides the above mentioned organisation of the artillery, towards the organisation of this fortified zone.

3. This fortified zone, and still more the battery positions, which should also have considerable depth and be extended well backwards, should be completely concealed and should include a certain number of points of support, distributed backwards as well as laterally, which serve to prevent the deployment of the enemy in this zone.

4. A point of support should consist of a central shell-proof subterranean barracks, with a certain number of mine galleries radiating from it; each of these galleries should have its outlet at a point from which the surrounding ground could be observed; each of these outlets, which ought to be well-concealed, should consist of a small dug-out for the men and material—machine guns, rifles or anti-tank guns, searchlights or, better still, rifles for signalling—protected by a network of obstacles. These supporting points should be big enough to allow for the concentration there, at a given moment, of several battalions of artillery.

5. The intervals between these works should be protected not only by the mutual flanking fire of their moats, invisible barbed wire entanglements, etc., guns and other engines of war, but also by obstacles. As these obstructions are in a great measure independent of the outlines of the works, they do not show up the position of the latter.

6. Finally, for the defence of a fortified position, a very well-trained and instructed garrison is essential; militia formations should never be employed.

Topography from Aerial Photographs.—The Corps of Engineers and the Air Service are at present co-operating on mapping work in the Upper Tennessee Valley, in connection with navigation improvements, and hydro-electric schemes. This article contains a description of the methods employed and a discussion on the possibilities of air photography in this field.

(*November-December*, 1924.)—*Problems involved in Coast Erosion.*—An interesting study of the action of waves on a coast. Their effect is dependent principally on the following factors:—

1. The size and character of the waves.
2. The direction of their approach.
3. The profile of the beach and of the bottom of the adjacent shoal water.

The effects of storm waves and high winds are discussed at some length. The article concludes with a list of conclusions and recommendations which have been adopted by the Engineering Advisory Committee of the United States.

As these may well be of value to officers of the Corps, they are given as follows:—

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1. Neither bulkheads nor groynes can be recommended for use singly, except in special cases.

2. The use of concrete for bulkheads is not recommended, except for those heavier and more permanent types that may be classed as sea-walls.

3. Timber bulkheads should always be provided with riprap protection. To be most effective, there should be added to the timber jetty or groyne a bank of riprap on each side. The riprap should be of substantial size and the whole bank of riprap with the timber groyne should have a width at the top of from 12 to 20 feet, dependent on the locality; the purpose of the riprap being to add substance to the groyne and to decrease the scour of the receding waves, the purpose of the timber work to constitute a tight core.

4. The construction of bulkheads seaward of the high-water line should not be permitted, except for urgent reasons to the contrary.

5. The groynes must be spaced dependent on the slope of the beach, and the location of the inlets; the steeper beach necessitating groynes closer together than the flat beach. Also, it is not believed that any benefit, except in isolated cases and under particular conditions, will result in the groynes being otherwise than straight and generally normal to the beach.

6. Groynes should always be securely connected back to a bulkhead or, lacking that, to the line of sand dunes or other points well above the high-water line.

Sheet piles should be never less than ten feet. Riprap should not be less than one-man stone pieces weighing about 100 pounds. The larger the stone the less the effect of wave action upon it.

7. Groynes for purposes other than that of holding the beach should be permitted only for special reasons and after careful study.

8. A sand-tight core should always be provided for groynes. Either sheet piling or a compact one of gravel, quarry refuse, etc., may be used.

9. The core should always be solidly protected by piles, riprap, or by both.

10. Groynes more than three feet above the normal profile of the beach should be permitted only for special reasons. The top of the groyne should conform to the general slope of the beach and should be, on the average, three feet above the level of the beach, and, where erosions have occurred in the past, and it is desirable to recapture the beach and restore it, the groynes should be designed with the piles projecting up, so that additional boards may be added between the vertical piles if the beach rises.

11. Care should be exercised in permitting the construction of curved groynes.

12. Groynes should be spaced, roughly, a distance apart equal to their length.

13. The growth of sand dunes along the coast should be encouraged and promoted. They are best promoted by aiding the

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growth of beach-building vegetation, such as sea-oats, sea-wheat and other beach plants.

14. The littoral drifts are of insufficient volume and velocity to warrant the construction of any key works in the way of heavy outshore jetties or current deflectors; that such works are not considered necessary, desirable or justified.

15. That to control the location and navigable depth of inlets, tight jetties are necessary, and that in the case of many inlets two parallel jetties are needed to carry the current into deep water.

16. These jetties may be straight where the tidal prism of the lagoons or bays is large, but may be curved in order to increase velocity where the lagoons or bays are small.

17. In the construction of jetties to control the entrance to inlets, great care must be exercised that such works do not cut off the supply of sand on which beaches adjacent to the inlet depend.

18. The public authorities should discourage, as far as lies within their power, the construction of sand-catchers or arrestors designed and placed for the purpose of extending the high-water line or the low water line toward the sea. Whatever is done in the way of coast protective works should be as such and not as coast extension works.

A Rapidly Constructed Military Road.—The ordinary corduroy road is extravagant in labour and material. A modification of this type has recently been tested with satisfactory results. Timbering is confined to the two wheel tracks. These are first excavated two feet wide by four inches deep, the spoil being used to form the crown. A double course of 2-inch planking is then laid, breaking joint. Two wheel guides of suitable section, secured to the inner edges, prevent the wheels from leaving the track.

As a rapid expedient on reasonably good ground, this method of construction is worthy of note.

R.I.M.

COAST ARTILLERY JOURNAL.

(*July*, 1924).

AFTER practice shoots at Hawaii, it was decided to do away with Machine Gun Batteries for Anti-Aircraft work, and accordingly the M.G. Battalion of the 64th Coast Artillery (Anti-Aircraft) was reorganised as a second gun battalion identical with the first. But each battery of both battalions was supplied with four machine guns as alternative armament and for local protection.

Last year a Board of Officers was appointed to conduct tests to determine the efficiency of aerial bombing and of anti-aircraft fire. The report by the anti-aircraft batteries gives the impression that the bombers would have to maintain a height of some 20,000 feet or be brought down. It would be interesting to see the report of the Hawaiian Air Force.

As regards night firing, the author writes that the finding of a plane at night and its illumination for the guns is the hardest problem which

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confronts this branch of the service at the present time: he advocates distant control for the lights and increase of destructive radius for the shell.

The target for A.A. fire consisted, by day, of a group of eight or ten red toy ballons released in such a way that they would float past the battery on the wind at about 5,000 feet, or, for night or day practice, of a cylindrically shaped cloth sleeve towed some 2,000 yards behind an aeroplane. The sleeve was 5 feet in diam. and 8 feet long for 4,000-6,000 feet and increased to 10 feet in length for 8,000 feet. It was found that a red sleeve gave best results by day and a white one by night. No danger was apparent to the towing plane, though the original tow line was 3,000 feet long.

The percentage of hits in five days' practice averaged from 11 per cent. within 50 yards to 49.7 per cent. within 100 yards.

Dishpan or open type lights were contrasted with barrel type lights and the results found may be tabulated as under. It is proposed to try aluminium for the body of the lights in order to obtain lightness.

Advantages of barrel type: (*a*) Automatic features can be incorporated in lamp mechanism. (*b*) More rigid frame prevents distortion of mirror. (*c*) Arc protected from wind and consequent increase of illumination. (*d*) Mirror does not get fouled with insects or dust. (*e*) Lower cost of maintenance in mirror breakage. Advantages of open type: (*f*) Lighter for transport and manœuvre. (*g*) Small trunnion height needs lower emplacement for protection. (*h*) Minimum shipping space; this type could be packed in nests. (*j*) Mirror kept cooler with less chance of fracture. (*k*) Lower cost of production. (*l*) No front doors to absorb light.

The Board finally decided in favour of the barrel-type light. They also reported upon the necessity of remote electric control to enable the operator to concentrate all his attention on the target.

An impulse type controller is now being tested, with following results:—(*a*) The operation of control synchronising with the light is not necessary and is, therefore, undesirable. (*b*) A disengaging mechanism is necessary to make the light independent of the control when required. (*c*) The controller motors must be operated from the searchlight power plant without interfering with the power necessary for the efficient maintenance of the arc. (*d*) The speed of the controller must be sufficient to enable the light to keep up with the target. (*e*) There must be no appreciable lag in the response of the light to the control. (*f*) The method of control should be in the form of a "Joystick" or single lever which can be operated in two directions at right angles to one another, one for vertical and the other for horizontal deflection. (*g*) The control must be light enough to enable the observer to change position and take advantage of maximum visibility at all times.

The Board also reported that the high intensity light should receive the greatest attention and development and that medium intensity lights may probably be omitted entirely as a result of future tests. Targets would probably not fly under the conditions of visibility in which the medium intensity light is theoretically superior.

D.M.F.H.

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INFANTRY JOURNAL.

THE January, 1925, number of this Journal, published by the United States Infantry Association, of Washington, gives an account, by Lieut. Geo. T. Wyche, 16th Infantry, of the construction of a Concrete Relief Map. Relief maps, for use in the instruction of tactics, etc., had hitherto been made of sand, but it was recognised that something more stable was required for a map of sufficient size to be suitable for practising the manœuvring of a division. The map built by Lieut. Wyche was laid on the floor in a box 15 feet wide, 45 feet long and 12 inches deep. A mixture of one part cement to four parts sand was found to give sufficient strength to permit walking on the map without damage. About half the depth of the box was filled in with cinders, and concrete was used for the top half only. The map was reproduced by the ordinary methods, it represented a base port at one end, leading to hilly country, with roads, railways and the usual features. When the concrete had set the features were painted in, and woods were made by dropping concrete, about a handful at a time, from a height of about six inches, and were later painted with green water paint. Small houses and wooden bridges were placed on the map at the necessary points. Towns were only outlined—streets painted white with a house at each corner of each block. The features were named on small cards held upright in slots in small blocks. The scale of the map was fixed at 3 ft. to one mile, and 250 yds. sub-divisions were painted on the outside of the box and numbered to provide map co-ordinates. The scale was increased when the map was used for the manœuvres of small bodies of troops. The map was built in sections of 2ft. by 15 ft. at a time and took one officer and five other ranks some 60 hours to complete. The troops were represented by painted wooden blocks. The writer describes the various uses to which the map is being put at the Post Intelligence School, Fort Jay, N.Y., in map-reading, patrol and scout tactics and O.P. locating and functioning. Activities in front of the O.P. are simulated by means of small blocks of wood, toy balloons, etc. In the two months during which it has been in use the map has shown that its uses for instruction in tactics are practically unlimited. F.E.G.S.

SÕDUR.

THE Esthonian weekly military paper, "Sõdur" (The Soldier) of 15th January, 1925, reproduces from the Red Army News "The Krasnoarmiets," No. 61, of July, 1924, a large picture of Zinovieff, backed by five small pictures of gigantic crowds, intended to impress the Red Army with the immense strides which Communism is making in foreign countries. One of these has unfortunately been recognised as a photograph, by Akel of Reval, taken on the occasion of the Esthonian Great National Singing Festival held at Reval in June, 1923. To represent this loyal gathering as a "crowd demanding the abolition of the capitalistic regime and organisation after the example of the Soviet Republics" has come as no small shock to the Esthonians, who stigmatise it as a "trick, probably second to none in the World's history." F.E.G.S.

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CORRESPONDENCE.

WARMING AND COOKING FOR SMALL HOMES.

To the Editor, *R.E. Journal.*

SIR,

Major General Ferrier in his letter in the September number opens up a subject of interest to many officers both from the personal point of view, and also from the official standpoint now that we are concerned with the building or adaptation of married quarters for officers as well as other ranks in many stations. The subject is one of infinite variety; depending on the size of the house and the requirements of the family, and I propose only to describe the work I have recently done in my house, which is about the size of a C.O.'s quarter, to show what is in my opinion the best arrangement in a house of that size.

My experience has been that the combination of cooking and hot water supply from one kitchen range is seldom satisfactory; either the ovens are cold or the water is tepid, and the fuel is to a great extent wasted in heating the chimney. I soon found in this house that the boiler at the back of the range could not cope with the demand for hot baths, the connections were so faulty that even when the water was hot in the cylinder it could only be coaxed out of the bath tap by turning it on very gently; if it was turned on full, cold bored through at once and the result was tepid; the boiler cracked at the top as they usually do if worked at all hard, and something had to be done.

With the convenience of a gas cooker in the scullery I found the kitchen range was little used for cooking, and it served the third purpose of warming the kitchen only moderately well, and at much expense for fuel. I decided therefore, to clear out the old kitchen range, and to put in a modern table type gas cooker in the scullery, on which all the cooking could be done. In place of the kitchen range I installed a No. 2 " Glowworm " boiler to warm the kitchen, and the house, and, from this, connection was made to the existing hot water service with some little modification to get the connections quite satisfactory.

With an independent boiler for hot water supply I see no reason why advantage should not be taken of it to warm the hall and staircase by radiators, provided that the heating system is not overdone and arrangement made to turn it off at night, so that it does not compete with the heating up of the hot water in the morning; it is best I think, to take the heating pipes quite separately off the other side of the boiler as shown in the diagram. This saves a separate fire in the hall and gives a wonderful degree of comfort by the elimination of cold draughts about the staircase and landings.

Before commencing work I studied carefully the last edition of " Hot Water Supply," by F. Dye, and also lent it to the builder, and plumber, to read, so that we might all be in agreement about the important points on which the success or failure of a hot water system depends, viz.: where to connect the primary flow and return to the cylinder, where to lead in the cold supply pipe, where to take off the secondary flow or expansion pipe and where to return it.

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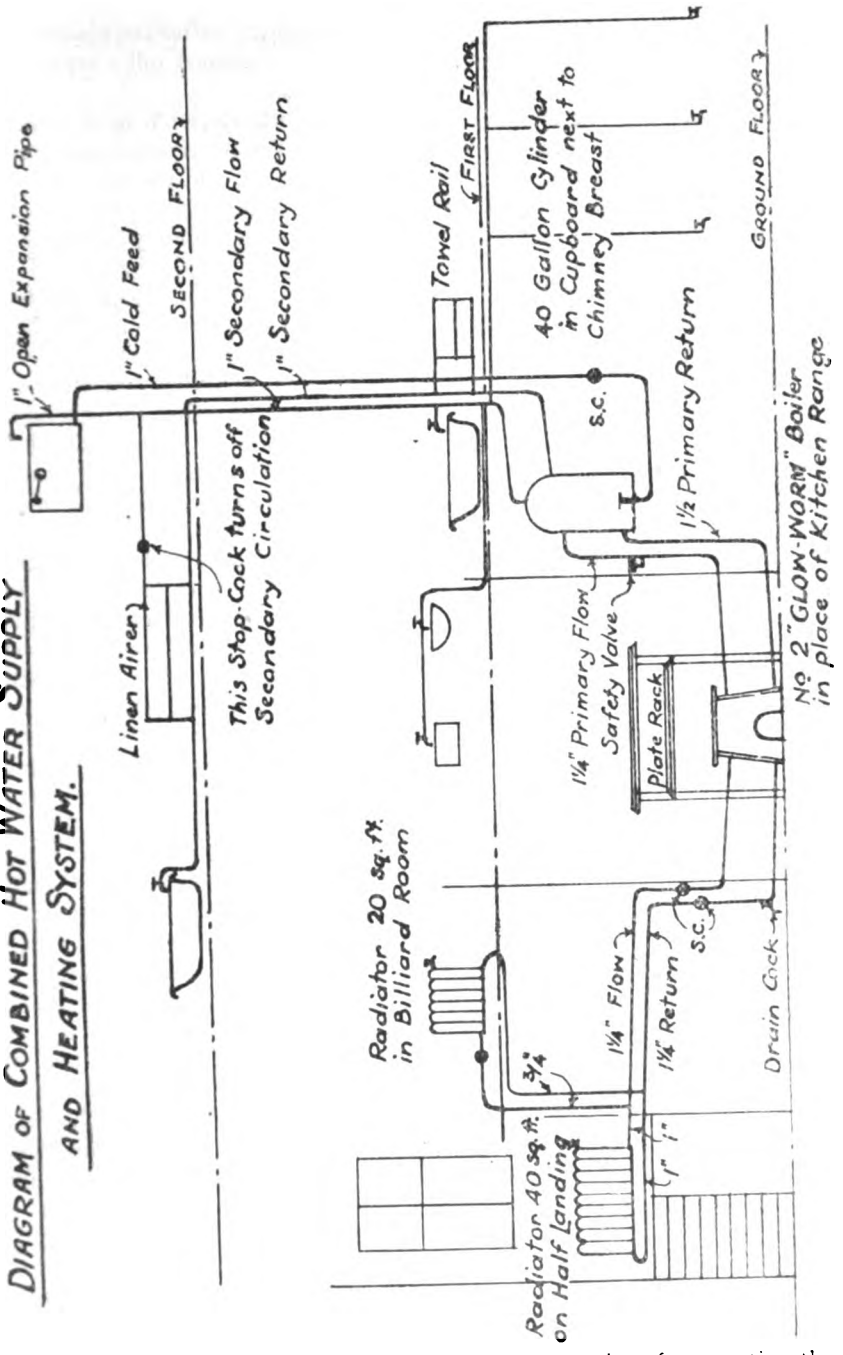

I can see no sense for instance in the common practice of connecting the cold feed to the boiler instead of to the bottom of the cylinder, it involves an extra length of some 10 feet of lead pipe and double that length of loss of head by friction when delivery at the taps is considered. Many a system is spoilt by bringing back the secondary return to near the bottom

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of the cylinder under the impression that thereby a better circulation will be obtained, the result being that when a tap is opened full a tepid flow comes, as I described was the case in this house.

The position of the cylinder is of great importance, let it be if possible on the direct route between boiler and bath. The nearer it can be to the boiler the better for quick heating up of the water, and the primary flow and return should be of ample size. I brought mine in from the cold lean-to scullery to a snug corner of the kitchen next to the chimney breast where it is just below the bath. It will nearly always, I think, be better to keep it below the kitchen ceiling level so as to shorten the run to ground floor taps, rather than to put it upstairs with the idea of warming the linen cupboard. I tried this once and did not find it a great success.

The connection to towel rails requires careful consideration otherwise they will not work, both connections should be off either the secondary flow or the secondary return, preferably the latter. It is desirable to arrange for a stopcock to cut off the secondary return, whilst leaving a clear open expansion pipe, so as to save loss of heat at night or in the summer when even towel rails may not be wanted. In the course of carrying out this work we struck by accident, what is perhaps the ideal connection; in making up the airing rail for the upper bath room and linen room the plumber used a crooked tee in the top connection to which the flow was led, the result being that the middle and lower rails were shorter by a fraction of an inch, owing to the right hand down pipe being slightly out of vertical. The circulation detects this in an instant and makes for the centre rail, instead of the top rail, returning by the lower rail, leaving the top rail to get what it may in due course. Any towels or linen hung to air get the benefit of the greater heat being below instead of in the top rail as is usually the case.

The work has all been completed some six months and what was a cold and draughty house last winter has been converted into a really comfortable one. Hot baths without stint can be had in rapid succession in either bath room, there is a plentiful hot water service at all taps throughout the day, and when the radiator is turned on at lighting up time in the afternoon a gentle warmth steals up the staircase and landings and takes the chill off the upstairs rooms, without giving any of that oppressive feeling of an overheated hotel. The cook has no flues to clean before lighting the fire in the morning, and in cold weather the Glowworm is banked up with coke and slack so that it keeps in all night. The maid has only two coal fires to attend to, in the drawing and dining rooms, there are gas fires in the study and billiard room for occasional use, and we find a little Kern stove or Beatrice gas heater ample in the bedrooms just to warm them up for dressing on a cold morning. Fuel consumption is appreciably less, the boiler burns no more coke than the old range ate coal, and the cost of the work will soon be repaid, apart from the appreciation in the value of the house.

E. N. STOCKLEY.

MILITARY TERMS.

To the Editor, *R.E. Journal.*

SIR,

A kindly critic of my TS. of a volume of the History of the War, suggested that certain military words used in it had better be explained

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for the benefit of non-military readers. I said that such persons could look them up in a dictionary. He said "You look them up in the Pocket Oxford Dictionary of Current English." I did, using the 1924 edition published at the Oxford University Press. I append a transcript of what I found. The italics are mine.

Your obedient servant,
J. E. EDMONDS.

BASTION	..	*Pentagonal* projection from a fortification.
BATTERY..	..	Set of guns with their men and *horses*.
CAMOUFLET	..	Smoke puff.
CAMOUFLAGE	..	Disguise of guns, ships, etc., etc., effected by obscuring outline with splashes of various colours; use of smoke screens, boughs, etc., for same purpose.
CAPONIER	..	(Not given.)
CASEMATE	..	Embrasured room in the thickness of fortress wall.
ESCARP ..	..	Steep bank under rampart.
FASCINE ..	..	A long faggot used especially in war for lining trenches, etc.
GABION ..	..	A cylinder of wicker or woven metal bands *filled with earth*.
LUNETTE..	..	Arched aperture in concave ceiling to admit light (fortification term not given).
PLATOON	..	Sub-division of a *battalion*.
PONTOON	..	Flat-bottomed boat or closed hollow metal cylinder for use with others as supports of temporary bridge.
REDAN ..	..	Fieldwork with two faces forming a salient angle.
REVETMENT	..	Facing of masonry, concrete, faggots, etc., *on rampart or embankment*.
SAP ..	..	*Noun*. Digging of siege trenches, covered siege trench (saphead, front end of sap). *Verb*, approach by sapping, dig siege trenches.
SAND-BAG	..	Jute bag filled with sand [one thing it won't hold] for use in fortification.
TAMP ..	..	*Verb*, Plug (blasting hole) with clay, etc., to intensify force of explosion.
TAMPING	..	Substance used for this.
TAMBOUR	..	[Not given.]
TROOP ..	..	Captain's cavalry unit corresponding to infantry company.

THE HISTORY OF SUBMARINE MINING.

To the Editor, *R.E. Journal*.

DEAR SIR,

I notice in recent issues of the *R.E. Journal* that though you are still advertising the complete set of three volumes of the *History of the Corps*, you have ceased to advertise the *History of Submarine Mining in the British Army*.* I venture to suggest that this omission may give

* Published by the Institution of Royal Engineers, Chatham. Price 5s.

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the present and future generations of R.E. a distorted view of Corps History. The Submarine Mining branch of the R.E. employed a large proportion of the Corps for a period of 40 years, and when the mines were handed over to the Navy the S.M. Service numbered nearly one quarter of the whole strength of the Corps and more than this proportion of what were then called the Auxiliary Forces. (R.E.)

When I compiled the record of the Submarine Mining Service at the request of the Committee of the R.E. Institute, I was in very close touch with Sir Charles Watson, who was compiling the third volume of the History of the Corps, and I frequently met him in the R.E. Library in the Horse Guards, where we were both collecting material.

Sir Charles Watson was himself an early Submarine Miner and the first officer in charge of the R.E. inspection branch at Woolwich, and his original intention was to devote some one or more chapters of Vol. III to the submarine mining work. But when he saw the first proofs of my book, he was good enough to say that it covered the whole ground so completely that he had decided to omit all reference to this side of the work in Vol. III of the Corps History.

Although the actual mine defences were handed over to the Navy the service really remained part of the Corps and was continued as the Fortress Electric Light Service, which did such excellent work in the war. It was also the parent of the Field Electric Light service, which was developed so largely for anti-aircraft work. Both these branches still have a definite place in the organisation of the British Army.

The organisation of the R.E. Reserve and Territorial units at the present time is also largely based on the experience of the Submarine Miners.

Without claiming any literary excellence for my own production, I feel justified in submitting that it is a fairly complete record of the work of a very large branch of the Corps of R.E., and as such should be treated as a permanent part of the Corps History.

Yours very truly,

W. BAKER BROWN.
Brig.-General.

Secretary, R.E. Institution.

NEW ZEALAND.

INFORMATION received from New Zealand states that during the present training year, which ends on 1st June, the whole of the three Field Companies will carry out their annual training at Trentham, which is the Headquarters Camp for the Central Command, and is situated at about 15 miles from Wellington. The Officers and N.C.O.'s of these Companies had a very successful course at Trentham in November.

Steps are being taken to complete the establishment of the Field Park Company, which under the new organisation will accompany the Division in the field, and good progress is being made in arranging with the Institution of Civil Engineers for some of its younger members to take up the first appointments in the commissioned ranks. The importance of securing professional engineers is fully recognised.

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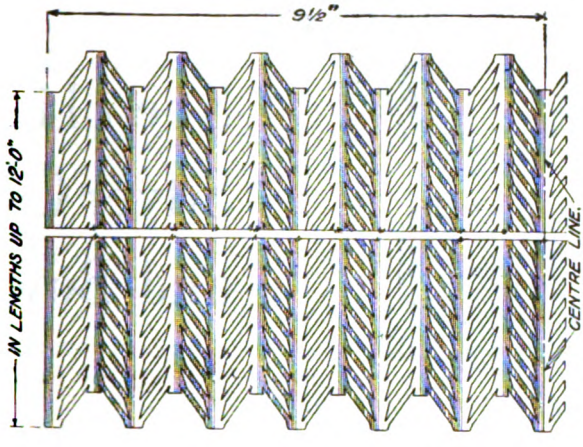

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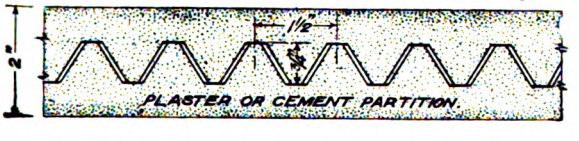

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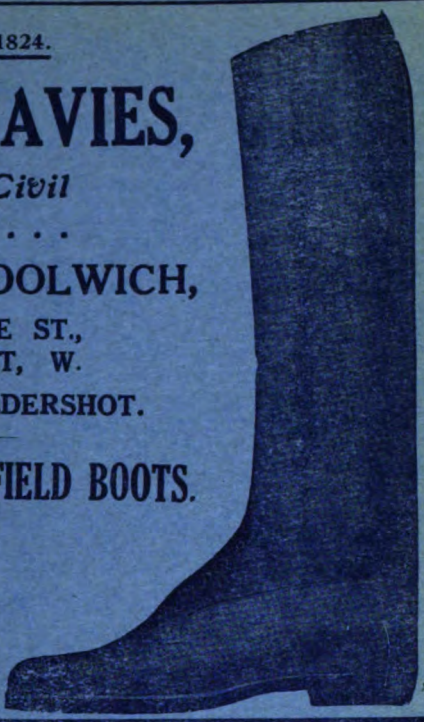

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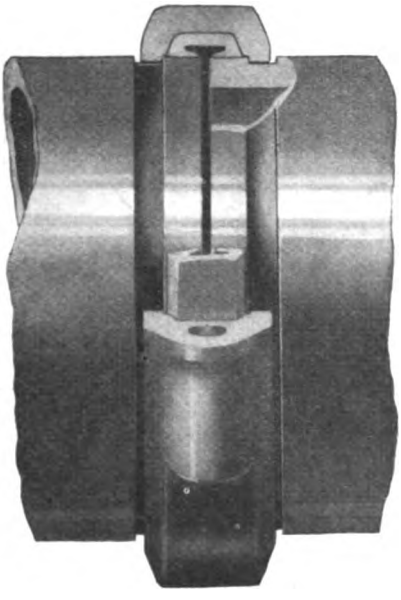

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THE INSTITUTION OF ROYAL ENGINEERS.

By F. E. G. S.

The Institution of Royal Engineers, of which this *Journal* is, perhaps, the most prominent outward and visible sign, was formed, as our Charter affirms, " for the general advancement of Military Science, and more particularly for promoting the acquisition of historical and scientific knowledge in relation to Engineering as applied to military purposes." It has now been in existence for fifty years, and the occasion of its Jubilee suggests an opportunity for looking back into its records and recalling the ideas which instigated its inception, and enquiring to how great an extent the hopes of those who took a prominent part in its creation have been fulfilled in its performance.

The date which has been taken as that of the inauguration of the Royal Engineer Institute, as it was first called, the 22nd May, 1875, is that of the sixth of the series of Annual Corps Meetings, the first of which was held in 1870. Long before this, in fact, since 1837, the officers of the Corps had subscribed among themselves for the publication of the *Professional Papers*, which had been published under the management of an important committee with a secretary and separate editor; and here it may be mentioned that the publication of this valuable series, the last item of which appeared as long ago as 1918, has never been considered as definitely abandoned, but many recent causes have led to its being held in abeyance, principally the lack of suitable contributions, for, owing to the growth of the *Journal*, many papers and lectures which would formerly have been published as *Professional Papers* now appear in the *Journal*, and partly also the increased cost of printing, which has led to the concentration of all available resources upon the single and more widely distributed publication.

The Corps Libraries were started in 1846, and, in 1870, besides the Libraries in London and at the S.M.E. and Dublin, they included 27 branches, as widely separated as Quebec and " Van Dieman's Land," St. Helena and Hong Kong. These also were mainly provided by subscriptions among the Officers of the Corps, but they have always received some official support, as the most suitable means of providing Engineer Officers with necessary books of reference.

The Royal Engineer Journal was first issued in 1870. At the first Corps Meeting, held in May, Major R. Harrison proposed and Captain R. Home, R.E., seconded a proposal, " That a Corps periodical should be started, if found practicable, embodying the

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proceedings of the Corps Meetings, etc., with a complete Officers' Directory." The motion "met with general approval, but in the absence of an organisation to conduct the contemplated periodical, it was not considered by the Meeting advisable that a formal vote should be taken upon it." The *Journal*, however, appeared in August, in the foolscap form in which it existed until 1905. The Editor was Major V. G. Clayton, and in an introductory notice it was stated that the new *Journal* was "far humbler in its aim than the *Professional Papers*," that it was intended "to enable Officers widely separated from one another to know what their brethren are doing and where they are quartered."

It must be gratifying to the veteran General, Sir Richard Harrison, to remember that among his many beneficial contributions to the Corps, this *Journal*, which we like to think is still read with interest in many quarters of the globe, owed its original existence to his initiative.

In 1905 the *Journal* was published in its present form, but was still issued monthly, and a *Supplement* was published separately to contain what may be called the domestic concerns of the Corps.

The *Journal* of 1905 was intended to include "articles interesting to the Army at large, and of a less technical and less fully illustrated character than those in the *Professional Papers*." The new venture proved a success, and in 1923 a further development converted the monthly *Journal* into its present quarterly form. If it has at the same time become more technical, perhaps at the expense of the *Professional Papers*, it is the hope of the Editor and of the Publication Committee that in this they have rightly interpreted the wishes of the members of the Institution.

The nominal Lists of Officers of the Corps were published as a *Supplement* to the *Journal* from the earliest days of its existence. In 1905 they were given the title of the *Monthly List*, and since the Great War the *Quarterly List*. They have always retained the foolscap size in which they were originally published.

For the inception of the R.E. Institute we must not look to private initiative. It appears to have been entirely official and originated in the erection of the building at Chatham, now called the S.M.E. Main Building, but for many years known as the R.E. Institute. It was designed by Lieut. (now Sir Montague) Ommanney under the directions of the then Inspector-General of Fortifications, Lieut.-General Sir Frederick Chapman, and was begun in 1871. On the 22nd May, 1872, H.R.H. The Duke of Cambridge, Commander-in Chief, laid the foundation stone. On its completion, early in 1875, a committee, consisting of Sir Lintorn Simmons, Sir Henry Harness and the then Commandant of the S.M.E., Colonel (afterwards Major-General Sir) Thomas Gallwey, who had been previously consulted on the accommodation required in the building, was

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The Celebration of the Jubilee of the In

Fifth Row. 35) Major R. P. Pakenham-Walsh, M.C., R.E. (36) Lt.-Col. D. K. Edgar, D.S.O., R.E.
(40) Major G. E. H. Sim, D.S.O., M.C., R.E. (41) L

Fourth Row. (29) Col. A. M. Henniker, C.B.E. (30) Lt.-Col. A. J. Savage, D.S.O. (31) Col. H. G. K

Third Row. (20) Col. H. L. Pritchard, C.B., C.M.G., D.S.O. (21) Col. Sir Gerald P. Lenox-Conyngham, Kt., F.R.S.
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econd Row. (10) Col. F. E. G. Skey. (11) A. R. Hinks, Esq., C.B.E., M.A., F.R.S. (12) Lt.-Col. W. A. J. O'Mear
(16) Col. W. Pitt, C.M.G. (17) Br.-Gen. W. Baker

First Row. (1) Sir Henry Tanner, Kt., C.B., I.S.O (2) Prof. C. E. Inglis, O.B.E., M.A. (3) Br.-Gen.
(6) Sir John Cadman, K.C.M.G., D.SC. (7) Loui

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re-assembled to report upon the manner in which the Institute should be organised and worked. From their report, which received the approval of the Commander-in-Chief and of the Secretary of State for War, a précis was presented to the Corps Meeting on the 22nd May, 1875, in which it was stated that the new building would accommodate a Professional Library, a Museum, a Lecture Theatre and Classrooms for the various courses of instruction then being carried out at the S.M.E. Stress was laid on the importance of preventing all possible interference with the scheme of the S.M.E., and, with this object, "the Institution (*sic*) should be placed for discipline under the Commandant of that School, and that he must have absolute control of the theatre, the schools, and all the establishments housed within it, and that no experiments made at the S.M.E., nor lectures, nor other matters connected with the course of instruction given at it, should be published by the Committee without the consent of the Commandant being first obtained." They were "of opinion that with the subscriptions now raised (for the *Professional Papers* and *Journal*) or which might be raised from the Corps, and by the sale, within approved limits, of publications, the School of Military Engineering may be made to contribute greatly to the circulation of useful professional information calculated to promote the progressive instruction of the Officers, and by their means to advance the public service."

With this outline of the plan, and a proposal to elect a Committee of nine ex-officio and 15 elected members, the Committee left the project in the hands of the Corps, who at the above-mentioned meeting adopted the proposal and elected by ballot the 15 unofficial members. It is needless to publish here the names of the original Committee of the Royal Engineer Institute, as they are given in full in the opening paragraph of the Royal Charter. The Duke of Cambridge was Patron and President, and Sir Frederick Chapman, succeeded on 1st July by Sir Lintorn Simmons, the I.G.F., was the first Chairman, or, at any rate, the senior ex-officio member, for it is not stated that he was definitely nominated as Chairman. Major Clayton, the editor of the *Journal*, acted as Secretary until Brevet-Major W. H. Collins was elected (in August), but the latter resigned within a year and was succeeded by Capt. R. H. Vetch, who held the appointment for seven years, until February, 1884. Up to 1910 the office of Secretary was held by an Officer on the active list of the Corps, but since that date by a retired officer.

The first annual report of the Institute was presented to the Corps Meeting held on 26th May, 1876—at one o'clock! It contains little of interest. The *Rules* had been drawn up and circulated to all officers of the Corps, and it proposed that the publications of the Institute should be the monthly *Journal* and half-yearly *Occasional Papers*. "should there be sufficient matter to justify'

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their publication. No copy of the original *Rules* can now be found in the Secretary's office. The *Journal* was taken over as a going concern and was issued free to members from the beginning of 1877. The *Occasional Papers* were in no way different from the *Professional Papers*, but a new series was begun in 1877.

Other work of the Institute was the support of classes in foreign languages and landscape drawing, the arranging of a few lectures, and the collection of objects for the museum—in three classes (i) geology and mineralogy, (ii) chemistry and electricity and (iii) artillery. In 1882 the Committee also took over the Model Room—formerly a Chapel—now the Museum—but then full of a heterogeneous collection of Corps archæologia, which gained nothing by the room being periodically used for Band Concerts. Later on, the Institute took up the publication of books, text-books for the S.M.E. and others. But perhaps the chief use of the new organisation, and one which made itself felt almost immediately, was as an information bureau. In the report for 1879 it is stated:—"Officers now apply freely to the Secretary for information and for books, instruments, etc., and some idea may be formed of the appreciation of the Institute by members from the large correspondence that takes place; during the year 1879 the Secretary having received and acted upon, and replied to, more than 4,500 communications." The present Secretary can assure members that in this direction the Institution fully maintains its vitality.

But the word "Institute" as applied to the building at Chatham rapidly became a misnomer. Accommodation was far too necessary at the School of Military Engineering for any, except the offices of the Secretary and his clerks, to be spared for Institute purposes. As the pressure became greater the library was removed to the Mess and the Museum was given up—the geological specimens, it is believed, are now in the possession of the Rochester Museum. There was no room at Chatham for an Engineer organisation independent of the S.M.E. The Institute Committee saw this from very early days. Colonel Vetch, speaking in 1904, said: "When the R.E. Institute was originally proposed, it was intended to reproduce for the R.E. what the R.A. had in their Institute at Woolwich. But when the Institute buildings were completed they were practically seized by the S.M.E., which was greatly in want of accommodation, with the result that an influential Committee found themselves without their Institute, in which, however, rooms were found for their Secretary and his clerks. The Committee could not even get their printing and lithography done, except occasionally as a favour from the Commandant. Under these circumstances it was considered that some provision should be made for the future, and the suggestion was made that, at any rate, all entrance subscriptions should go to a capital account . . . the

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Fund has grown to nearly £4,000; this is but a nest egg, but if it is allowed to grow, then at some future day a real establishment, either at Chatham or in London, may result, which would bear some resemblance to the original intention." The money, as we know, was soon after spent in freeing the Model Room from the incumbrance of social functions (by remodelling the theatre) and in developing the museum as a true temple of Corps archæologia—a pet scheme of Sir Richard Harrison, the brilliant success of which all who visit it must agree in acknowledging.

A proposal to provide "Premises for the R.E. Institute in London" had already been the subject of a lengthy discussion at the Corps Meeting of 1888, when it was complained that the Institute had become merely a Secretariat and that no provision was possible for meetings of members to hear and discuss lectures. It was suggested that the Corps Library should be moved into unofficial premises, which, with lecture and reading rooms, should be hired at the charge of the Institute. There was also an amendment to obtain the required facilities from the Royal United Service Institution, and this was finally carried. The negotiations were placed in the hands of a committee, who, in the following year, were obliged to confess that they had resulted in pious aspirations and "notes for future consideration" only. At the 1892 meeting it was announced that the negotiations with the R.U.S.I. had definitely failed and there was nothing for it but to continue to put by funds with which the object of the acquisition of an Institute building in London could be eventually realised. It must be considered as fortunate, in view of the lean years that were to come, that this heavy additional expense was never thrown upon the resources of the Institution. Few members will now be found to complain of the accommodation so generously provided for the Corps Library in London, except those who would like to see it moved bodily to Chatham; and should the desire arise at any time to promote lectures, with discussions, as a part of the Institution activities there is no doubt that a theatre—for instance that at the R.U.S.I.—could be hired for the occasion at a small cost. Further, it is doubtful if any Secretary could ever have desired to see his office moved from Chatham, where he has always owed so much to the generous assistance of the Commandant and the Instructors of the S.M.E.

It may be mentioned that at the same time as this proposal, another, to frame a scheme for a Portrait Fund for the Corps, was laid before the meeting and discussed, but when the above-mentioned amendment was passed, this other proposal fell to the ground.

The ill-fated R.E. Gold Medal was first proposed at the Corps Meeting of 1875, by Colonel (afterwards Major-General Sir Wilbraham) Lennox, V.C., for a prize essay, the subject of which should be set each year, and, after some counter proposals had

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been defeated, was unanimously agreed to. The first medal was won by Captain (afterwards Major-General Sir Thomas) Fraser against four other competitors, and he repeated his victory in the following year, when only two essays were sent in. The gold medal for 1877 was won by Lieut.-Colonel (now General Sir Richard) Harrison against four other competitors, and after that it was withheld for two years, when five and two respectively were the numbers who competed.

At the Corps Meeting of 1880, these results led to a long discussion, in which various proposals, of new terms under which a gold medal or some equivalent prize should be given, were put forward, and it ended in a decision that the award should be discontinued. The subject for the Prize Essay of 1880 had already been published, and the last R.E. Gold Medal was won against two other competitors by Lieut. R. da Costa Porter.

In 1879, the Committee elected the first Honorary Members of the R.E. Institute. At the head of the list was the name of the eminent chemist, Sir Frederick Abel, F.R.S. In proposing his election, Colonel Graham said that "considering how closely he was associated with them in their work, they could not propose the election of any civilian as their first special Honorary Member, who would be more acceptable or would do them more honour than Professor Abel." Since 1879 many men distinguished in the world of science have been closely associated with the Corps in its work and have honoured the Institution by accepting its Honorary Membership, and the recent gathering at Chatham, in celebration of our Jubilee, will be recognised by members as a gratifying reminder of the eminent men who rallied to the assistance of the Corps in the anxious days of the Great War.

In 1876 the new Secretary, Captain Vetch, proposed that the word *Institution* be substituted for *Institute*, but it was decided that the Committee had not the power to alter the name, and this change was not made until 1921. In 1881, however, an "s" was added to the names of all the Corps institutions, and we became The Royal Engineers Institute.

At the Corps Meeting of 1886 a proposal was adopted: "That the Committee of the R.E. Institute, in conjunction with the Trustees of the R.E. Widows' Society, are authorised to take the necessary steps for the incorporation of the Corps under a Royal Charter, with a view to the appointment of Trustees, with a Common Seal to hold the various Corps Funds now or hereafter to be established." The petition was duly made to the Privy Council, and in 1889 it was announced that the law officers of the Crown had decided to refuse it. Further applications, made during the following year to the law officers by the I.G.F., Sir Lothian Nicholson, remained unanswered, and the I.G.F. was bound to admit that the law officers

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" had certainly not treated them courteously." The Institution, without the co-operation of the Widows' Society, made a similar petition in 1922 and was successful, and the Royal Charter was granted by the present King on February 27th, 1923. The present title, " The Institution of Royal Engineers," was adopted by the Council on 22nd July, 1921.

An account of the activities of the Institution would be incomplete without a mention of its usefulness in the collection and administration of Corps Funds—War Memorial Funds, Portrait Funds and other Memorials to individual officers and other ranks of the Corps. From the very first its use as " an organisation " capable of conducting these schemes declared itself, and the long list of medals and prizes still administered by the Institution, which led recently to the decision that this form of Memorial must be restricted in future, represents but a fraction of the many funds with which it has dealt in the fifty years of its existence. The administration of the Scholarship Funds, resulting from the Memorial of the Great War, is, perhaps, the privilege of all others most treasured by the present writer and probably by all the members of the Institution Council. In this we are carrying on the great work, instituted by Sir Ronald Maxwell and the War Memorial Committee, as representatives of the whole Corps, past and present, in paying a tribute to the service of our Comrades who fell in the service of their King and Country.

In conclusion, it will probably be admitted that the Institution has developed on the lines of its greatest usefulness. Members of a military Corps have their messes and clubs at which they can meet, and being also members of the larger organisation—the Army, or, rather, of the Armed Forces of the Crown—would probably make greater use of the Royal United Service Institution than of a building of their own, did such exist in London. They do not experience exactly the same necessities of association as their brethren in the Civil branches of the Engineering profession. But they do require—widely separated and isolated as they so often are—to know what other members of their Corps are working at and achieving, what views and opinions are operating at the War Office and the S.M.E., and what have been the developments in the various branches of their profession since they last were in touch with these establishments. These wants the Institution does its best to supply. Through the Institution and the pages of this *Journal* they can further, to a certain extent, keep in touch with the progress of the science of military engineering and of military thought in the Armies of foreign Powers, while the exchange of the *Journal* with those of the engineering branches of foreign Armies is a friendly " gesture " which should appeal to all who recognise the importance of international courtesies. As an example of this

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last, a letter may be quoted recently received by the secretary from the veteran American engineer, General Henry L. **Abbot**, who writes from Massachusetts (March 20th, 1925): "Please accept my thanks for the copy of the *Royal Engineers' Journal*. I have seen my 93rd birthday, and I assure you it is very pleasant to be remembered by old friends."

The Institution has no motto. Should we adopt Earl Kitchener's "Thorough"? Another suggestion is "In Armis Scientia."

Or perhaps some would prefer the following, as quoted on the title page of Sir Francis Head's book, "The Royal Engineer," published in 1869:—

Enter Some bringing in the Clerk of Chatham.

SMITH: The Clerk of Chatham: He can write and read and cast accompt.

CADE: Here's a villain! . . . . Away with him, I say: hang him with his pen and inkhorn about his neck.

(*Exit one with the Clerk.*)

Second Part of Henry VI., Act IV., Sc. **2**.

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THE POSITION OF ENGINEERS IN THE ARMY ORGANISATION.

A LECTURE PREPARED FOR DELIVERY AT THE S. M. E. ON 15TH JANUARY, 1925, BY MAJOR-GENERAL H. F. THUILLIER, C.B. C.M.G. DIRECTOR OF FORTIFICATIONS AND WORKS, BUT NOT DELIVERED OWING TO ILLNESS.

WHEN speaking of the position of engineers in the army organisation I do not refer to the tactical or technical employment of engineer units, but to the position and functions of the senior engineers at the headquarters of Corps, Armies and at G.H.Q. This subject has been one of controversy for a great many years past. Fifteen to twenty years ago, when the organisation of our modern army was being fashioned by the then newly-created General Staff, views of the most diverse nature prevailed regarding it and no definite doctrine or policy was formulated or promulgated. During the War, when that organisation was being melted down in the crucible of the world-struggle and re-cast on a vastly broader scale, the question was still officially unsettled, with the result that in every formation the difficulties of working without a fixed conception of what the position of the senior engineers should be in relation to the rest of the staff organisation frequently became very apparent. Since the War we have been engaged in sorting out from our experiences some principles to guide us in forging an organisation suitable for conducting our future wars. The time has now come, not only to decide and lay down definitely what these principles are in the subject now under discussion, but to instil them into all who may have to work them so that they may be accepted loyally and carried out unquestioningly.

Let us first consider the organisation of the Army. In this connection I do not mean merely its division into formations or the composition of those formations in the various arms, but I mean also the whole method by which the plans of the Commanders are formulated, issued to subordinates and carried out, and the system under which the various arms and services co-operate for the furtherance of those plans.

It is evident that the organisation in the above sense is liable to change. This must be so, for without change there could be no progress. The normal developments of invention are always bringing about new weapons and new tactics, and these in their turn necessitate changes in organisation and in the methods of control.

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Progress in weapons directly affects methods of control. You will no doubt remember that 150 years ago, if one may judge from the artists of the period, generals led their troops to the attack riding at their head, in conspicuous uniform and a cocked hat. The enemy against whom they were thus acting was armed with a flint lock musket, ranging not much over 200 yards, and after it had been discharged requiring about nineteen motions to reload it from its muzzle end. The modern leader has, alas! had to abandon this inspiring practice and to adopt methods resembling those of that famous nobleman, the Duke of Plaza Toro, who, you will remember, not only led his army from behind, but also was noted for digging himself in deeper than any of his gallant men. To these mean shifts we have been compelled by the advent of the machine gun and the high explosive shell.

As I have already said, the experiences of the Great War afford us the opportunities of formulating an organisation suitable to the conditions of the next few years, as far as we can visualise them. When we come to the position of the engineers in that organisation we must not confine our regard to the personal status, rank or dignity of the officers holding the senior engineer appointments, but must look at the question from a more objective point of view. What we want to consider is how to ensure that the engineer troops, plant and stores are used to the best effect in co-operation with the other arms, and how to permit of the great resources, which engineering science in these days makes available, being employed to the utmost extent practicable in the assistance of the Army in its mission, whatever that may be.

There are many who believe that the best way of securing these ends would be to have at the headquarters of an Expeditionary Force an Engineer-in-Chief in whom is centralized the whole of the engineering operations of the Army. Following the theory that the best and most economical results are obtained by co-ordination and centralization of authority—which is quite true—they would have the Engineer-in-Chief control the engineer work of all the formations subordinate to the Commander-in-Chief, by direct action through engineer commanders in each formation right down to the division. They would have him also control all work on the Line of Communication and at bases, through a Director of Works subordinate to himself.

The argument in favour of this last is that control of works entails control of the available stores with which works are carried out, and that only an official at G.H.Q. acquainted with the plans of the Commander-in-Chief and in touch with all branches of the Staff, can judge of the relative importance of the Line of Communication works and the field engineering needs of the fighting troops.

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There are even some who would go further still in the direction of centralization of engineer control and would place under the Engineer-in-Chief the transportation services, that is to say, the construction, maintenance and operation of railways, and I have heard it suggested that the organisation for surveys and map production, which requires engineer personnel, should be divorced from the General Staff branch and put under the Engineer-in-Chief, and, indeed, that the latter should be responsible for everything throughout the army which is of the nature of "engineering" and requires personnel of the Royal Engineers.

This school would similarly in peace have at the War Office an Engineer-in-Chief who would control all branches of engineer activity, would be the "Head of the Corps," and, as some have suggested, be a member of the Army Council. We will defer for the moment the consideration of the organisation in peace and confine ourselves to that for war.

How is an army organised in war? Every one knows the pivot of the army organisation is the division, which is the smallest formation composed of all arms and capable of acting alone. In the division all the arms, infantry, artillery, engineers and cavalry (if there are any), are under a single commander. Remember this—it is the basis of all army organisation, several arms under one commander, and it is *only in the division* where one commander directly commands them.

Two or more divisions constitute a corps, which may also have certain "Corps Troops," principally artillery and engineers, who are directly under the corps commander. Two or more corps are an Army, and two or more Armies compose the body which we know by the curious title of a "British Expeditionary Force."

Now, remember that all orders go from the Commander-in-Chief to the Army Commanders, from Army Commanders to Corps Commanders, and from Corps Commanders to Divisional Commanders. They are always issued by superior commanders to the *commanders* of the formations immediately below; *never*, by any chance, direct to units which form part of a subordinate formation. It must always be borne in mind that an Army—or, say, rather a "British Expeditionary Force"—is not composed of infantry, cavalry, artillery, engineers, &c., but of armies, "corps" and "divisions." It is *only* the division that is composed of infantry, cavalry, artillery and engineers, each under separate commanders, but in the higher formations this is not the case, except in a very limited degree in the case of certain troops additional to the divisions, who are directly under the Corps Commander.

Now, I ask you, keeping that organisation in view, how can an Engineer-in-Chief at G.H.Q. exercise direct control over the engineering work of the formations subordinate to the Commander-in-Chief?

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To do so he would require to give orders to the engineer commanders of the subordinate formations, and how could he give orders to some one who is under a Corps Commander or a Division Commander? The answer is, he *cannot*. The Engineer-in-Chief *cannot* function as executive controller of the engineer work carried out in Armies, Corps and Divisions—Neither can Chief Engineers of Armies or Corps perform such functions. The only officers who can exercise functions of executive control, in other words, of command, are Commanding Royal Engineers, *i.e.*, Commanding Royal Engineers of Divisions and Commanding Royal Engineers of Corps Troops.

What, then, are the functions of the Engineer-in-Chief at G.H.Q. and of Chief Engineers of Armies and Corps? Do we want any at all? Yes, we do, and their functions are most important. These functions are, however, entirely of an advisory nature; the Engineer-inChief and Chief Engineers have no responsibility for methods of execution, and do not exercise any powers of command. Orders to subordinate formations are, and must be, issued by the staff of the higher formation concerned.

There are officers, both senior and junior, who believe that the doctrine that Chief Engineers and Engineers-in-Chief should be only advisers and not commanders is in some way a lowering of their status and a lowering of the dignity of the Corps—With such opinions I am in total disagreement. I would remind those who hold them that engineers are combatant troops. Now, combatant units must be under the command of the commander of their formation. Their chain of command cannot run through specialist chiefs from bottom to top. Services where the latter is the practice are departmental services. To bring about this practice in the case of the engineers would be to departmentalize the latter, to lower its status from that of a combatant branch to that of a departmental service.

So far I have been talking about field engineering work, namely, that work which is intimately connected with tactical operations in progress or in contemplation. There are, however, other classes of engineering work which are equally important and take up an equally large, and sometimes even larger, share of the activities of the engineers in a theatre of war. These are labelled in F.S.R., Vol.I, as "Works Services" and defined as "all engineering work of a general nature not having an immediate bearing on tactical operations in progress or in contemplation." They cover, practically, all work at the bases and on the line of communication, and even in the zone of the armies they cover most of the works connected with the movement, housing, comfort and health of troops and animals behind the actual fighting zone. These works are carried out under the direct responsibility of the Director of Works and his representatives. Where the magnitude of the operations warrants

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it, work in connection with the railways, docks and harbours in the theatre of war will not be under the Director of Works but under a Director of Transportation.

Now to return to the query suggested previously. Why should not these directors, whose functions are of an "engineering" nature, be subordinate to the Engineer-in-Chief?

The answer is exactly the same as in the case of the Engineer-in-Chief and Chief Engineers in connection with Field Engineering. In the same way as there are Army Commanders, Corps Commanders and Division Commanders controlling the operations of definite sub-divisions of the Expeditionary Force, so also is there a single official responsible for everything connected with the supply of that force. Under our present regulations that official is the Q.M.G. He is responsible for the transportation of the troops and stores to the theatre of war, for the organisation of the bases, for the provision of food, ammunition, equipment and stores of all kinds, for the transportation to the fighting zone of reinforcements, for the removal of wounded and the provision of base hospitals. He, and he alone, can say what quarters, stores, factories, railways, roads, wharves, docks and engineer works of all kinds he requires for the performance of these services, and the necessary works will assuredly not be carried out rapidly and efficiently unless the Director of Works functions in direct subordination to the Q.M.G. To give the Engineer-in-Chief any authority to direct or to interfere in any manner with the control of work on the Line of Communication would have a similar effect, and probably, in a greater degree, to that of allowing him to give direct orders to the Chief Engineers who are subordinate to Army and Corps Commanders.

But, it may be argued, what about the control of engineer materials and stores?

These are limited in regard to the quantity available in the theatre of war. Is it to be tolerated that the Director of Works shall have a free hand in deciding how much of the available stores he shall take for use on the Line of Communication Works, regardless of the wants of the fighting troops, for works connected with tactical operations? Certainly not. It is undoubtedly necessary that some one at G.H.Q. shall decide the relative priority of field engineering work and work on the Line of Communication respectively. The inadequacy of stores for the former might result in inability to undertake a tactical operation which depended on some engineering work, or might seriously affect the security of some part of the line occupied by the armies. But the person to make this decision is not the Engineer-in-Chief.

I have said earlier that it is true that the best results are obtained by co-ordination and centralisation of authority. I say it again. But I mean that the centralized authority should be that of the

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Commander-in-Chief—not that of the Engineer-in-Chief. It is the authority of the Commander-in-Chief, exercised by or through the Staff, that must settle the question of whether field engineering requirements or those of the Line of Communication shall have precedence.

Now I know that this theory—that the function of control or management should be vested in the Staff and not in the Engineer-in-Chief—is one that some engineer officers dispute. They hold that such control can only be exercised by those having the technical qualifications of the engineer.

Let us consider the question from a detached point of view. The control of an army, in this particular connection, does not differ in principle from that of a great civilian undertaking, such as a line of railway or a manufacturing business. In the latter " engineering " forms an important proportion of the work (probably a larger one than in the Army)—and there will very possibly be an engineering branch with a Chief Engineer at the head of it. But the Chief Engineer, as such, is not responsible in any way for the management of the business. For the latter there will be a ' management branch,' probably under a ' General Manager,' which co-ordinates and controls the work of the engineering branch, the stores branch, the production branch, the sales branch, the publicity branch, and what not. The management branch obtain technical advice, designs, estimates, &c., from the heads of the engineering and other technical branches, and on these they formulate proposals for the decision of the general manager or other ultimate authority.

In the Army there is also a ' management branch,' namely, the Staff, acting as representatives of the Commander-in-Chief. The control, that is to say, the rationing, of all stores, munitions and supplies of every nature, is and must be their function. This must be looked on as one of the basic principles of war administration.

It is essential, on the one hand, that none of the technical branches shall usurp that function, and, on the other hand, that the responsibility for it shall be definitely fixed on the Staff.

This, as regards engineer stores, has now been done. In the recent amendments to F.S.R., Vol. I, it is for the first time clearly laid down that it is necessary that the Staff should—

(i) Control the supply of engineer stores.

(ii) Co-ordinate and control the general scheme of field engineering work and subordinate formations.

The amended regulations go on to describe in detail what the above responsibilities involve, in the case of Staffs at G.H.Q. and of subordinate formations. Time does not admit of discussion in detail of the duties thus laid on the General Staff and Q.M.G's branches, but it will be seen that the Staff as a whole is clearly charged with the following duties :—

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In regard to control of stores :—

(a) Estimating requirements of stores.
(b) " Rationing " to formations or areas.
(c) Transportation to sites where required.

And in regard to control of field engineering :—

(a) Preparation of general schemes of field engineering works, including demolitions, having in view the available supplies of labour, materials and transport.
(b) Organisation of any special arrangements, such as re-distribution of engineer units or provision of special plant, which such schemes may require.
(c) Allocation to subordinate formations of the works to be executed.
(d) Inspection to insure that subordinate formations are devoting their energies to progress on the lines ordered.

It has been argued, why should these functions be exercised by the Staff; and are they competent to do so? Admitting that an Engineer-in-Chief, or Chief Engineer, cannot give orders to the engineers of a subordinate formation, why should they not issue to the Commanders of subordinate formations the orders of their own Commander on engineer matters as his Staff Officer? In fact, should not the Engineer-in-Chief and Chief Engineers be Staff Officers?

The answer is, no! Such an arrangement would be contrary to the fundamental principles on which armies are organized. The Staff issue *all* orders to lower formations, whatever branch of the Service they concern. We do not and cannot have an infantry staff issuing the orders for the infantry, a cavalry staff issuing the orders for the cavalry, an artillery staff issuing the orders for the artillery, nor an engineer staff issuing the orders for the engineers. A combined staff issues all orders. To keep the engineer orders distinct from the others and issued by engineer staff officers would be a reversion to departmentalism for the engineers. If it were done for all branches we should have, instead of an army, a congerie of departments and combined action would be impossible.

It has been definitely ruled by the Army Council that the orders of the Commander-in-Chief in the field will be issued through three Staff Officers only—The C.G.S., the A.G. and the Q.M.G., Even if it were ever decided to add a fourth I cannot conceive that it would be an engineer staff officer.

The more one examines the functions which are described as those of the Staff in connection with field engineering work, the more one must recognise that they are in fact functions of "management," that is to say of command and administration, and must be exercised only by those who represent the Commander.

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As regards the competence of the Staff from the technical point of view :—Here is where the Engineer-in-Chief and Chief Engineers come into the picture. No staff could possibly carry out these functions without competent technical advice.

The amended regulations say :—" To assist the Staff in the execution of the responsibilities assigned to them, engineer officers are affiliated to the General Staff of G.H.Q. and Armies. Their functions are advisory ; they have no responsibility for methods of execution, and do not exercise any functions of command. Orders to subordinate formations are issued by the Staff of the higher formation concerned. The Senior Engineer Advisor at G.H.Q. is designated the Engineer-in-Chief and those at Army and Corps Headquarters Chief Engineers."

You will all, I am sure, be glad that the military titles of Engineer-in-Chief and Chief Engineer have been definitely and officially adopted for the designation of these officers. The title Chief Engineer is of great antiquity. Its use for the senior engineer for forces at sieges and in the field can be traced back some 400 years, and there is reason to believe that it dates from considerably earlier still. In the armies of Cromwell, Marlborough and Wellington ; in the sieges of Gibraltar, of Sebastopol and of Delhi ; in every war where a British army has fought, there have been Chief Engineers. The abolition of this time-honoured title and the substitution of the unmeaning one of Brigadier-General (or Major-General), R.E., as was actually done before the great war, merely on the grounds that the functions of these officers in a modern army are different from what they were in other days, was a sad example of unnecessary destruction of a Corps tradition.

There are certain points in the new regulations, which I should like you to note. You will observe that the Engineer-in-Chief and Chief Engineers are " affiliated to the General Staff." It is the General Staff whom they will advise and for whom they will prepare the estimates of requirements of field engineering stores and the general schemes of field engineering works. You will also observe that it is definitely laid down that the General Staff are responsible for ascertaining from the Q.M.G. branch of the staff whether the required stores can be produced and whether transport is available for them to the places where they have to be delivered. In the past, in the absence of any definite regulations, this responsibility has generally fallen on the Chief Engineer. When the latter has obtained the General Staff's acceptance of a programme of works involving a considerable supply of materials, it is often left to the Chief Engineer to arrange for the supply of the latter. If he subsequently discovers that the movements branch cannot transport it the blame for the failure of the programme of works is apt to be laid at the door of the Chief Engineer. But field engineering works are " operations,"

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and the General Staff, before deciding on an operation, have the duty of ascertaining from the supply and movements branches whether the necessary materials and means of transport are available. If they are not, then it is for the General Staff to decide whether the engineer stores are of such urgency as to be given priority of transport over other stores (such as ammunition), or whether the works shall be abandoned. This is essentially a decision for the Staff and not for the Chief Engineer. The latter's position will be strengthened by not having to wrangle for transport with the "Q" staff himself.

Another point to notice is the function of the Chief Engineer of a corps which differs from that of the Chief Engineer of an army. Normally he, like the others, has advisory functions only, but it is expressly provided that at times centralized control of Engineer work may be called for, and at such times at the discretion of the Corps Commander, the whole or any portion of the corps and divisional engineers may be concentrated under the direct control of the Chief Engineer of the Corps, who will in such cases issue orders direct to them. This is a parallel case to that of the Corps artillery adviser, who may sometimes for a specific operation be put in charge of all the artillery of the Corps, including divisional artillery, who are temporarily withdrawn from divisional control.

Also Chief Engineers of Corps and Armies, and even the C.R.E. of a division may on occasion be required to act as the agent of the Director of Works for the execution of specific and important "works services" which may have to be carried out in an area occupied by a fighting formation. Such services might be hutting or water supply schemes or large schemes of road communication, and in these cases, and only in these, they would of course exercise executive functions. It is to be hoped that such occasions will not often occur, since the Chief Engineer concerned may then find himself subject to the difficulties which arise when men serve two masters, but there are few engineer officers who do not frequently find themselves in that situation and have to meet it with tact and goodwill.

The Director of Works who, under the regulations, controls the Works Services in the theatre of war, is not, like the Chief Engineers of Armies and Corps, an adviser only. He does himself directly administer and control the works on the Line of Communication and at bases, and carries them out by the agency of C.R.E's and other officers who are directly under him. The reason for this difference is obvious. As I have said before, tactical operations are not carried out departmentally. G.H.Q. issue instructions to the Armies, Army H.Q.'s to Corps, Corps H.Q. to Divisions, and the actual field engineering work is done by the Divisions. In the other case the Q.M.G. directly controls the

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administrative services on a departmental basis. The heads of the supply, transport, ordnance works, and other services are directly under him and each of the latter not only advises the Q.M.G. as to the possibilities of production of the particular service with which he is charged, but also arranges himself for production.

I need say no more about the position and functions of the engineers in the field, and in the short time remaining I should like to refer to an analogous question connected with the peace organisation. At an earlier stage in this lecture I mentioned that some of the advocates of a centralized control of field engineering operations by an Engineer-in-Chief at G.H.Q. would similarly like to see in peace at the War Office an Engineer-in-Chief, who would control all branches of engineer activity, would be the " Head of the Corps," and, as some suggest, a member of the Army Council.

Let us consider what this means and how it would fit in with the actual organisation of the Army Council and War Office as they are.

First of all, what is it that men have in their minds when they say we need a " Head of the Corps " ? I have often read arguments stating that a " Head of the Corps " is required in order to look after the interests of the Corps. Do those who say this mean the interests of the Corps as a regimental organization or of the engineer services of the Army ? They are not quite the same thing. The difference is of a similar nature to that between the infantry when spoken of as an arm of the service, and individual regiments such as the Gordon Highlanders or Durham Light Infantry. If the Corps as a regimental organisation is meant, then it is already provided with a Head to look after its interest. In the same way as infantry regiments have an Honorary Colonel, the R.E. have Colonels Commandant and have also the honour of having as Colonel-in-Chief His Majesty the King.

It cannot therefore be to regimental interests that the advocates of a " Head of the Corps " are referring, and the interests in question are, presumably, not " R.E. interests " (*with capital R and E.*) but " engineer interests," (*with a small e*), that is to say, *the interests of the Army in getting its engineers' services of all kinds carried out with efficiency*, which you will admit is a different thimg.

Incidentally it is a curious thing this practice of using a capital E instead of a small one. Many R.E. officers will unhesitatingly use a small *i* when writing of infantry organisation or infantry tactics, etc., but will invariably use a capital E (or even R.E.) when referring to the same subjects in connection with engineers. In fact, one sees this misconception cropping up in all sorts of unexpected places—in official correspondence, in official books of regulations and even in the *Army List*—and I can assure you that it has taken a lot of careful editing to keep it out of the training manuals.

Now, in order to ensure the efficient execution of all engineering

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work for the army in war and peace, would it be desirable, as proposed, to have a "Head of Corps," whether a member of the Army Council or not? Is there a "Head" of the infantry, the cavalry or the artillery? No, there is not, neither is there, nor can there be, under our Army organisation as it exists, a head of the engineers.

We must take the War Office organization as it exists. The Army Council has four military menbers only. Strange as it may seem, these are not members representing the infantry, the cavalry, the artillery, the engineers. Their functions are quite different. The Council is a council and its decisions are collective ones, but each military member is responsible for administering certain *subjects* for all branches of the Army. Thus the C.I.G.S. deals with training of the army in peace and operations in war. The A.G. with supply of men, their organization in units, and their discipline. The Q.M.G. with provision and distribution of clothing and equipments and with moving and quartering. The M.G.O. with production of weapons, *i.e.*, guns, rifles, machine guns, ammunition, tanks, etc., and also with construction and maintenance of barracks and fortifications.

How would it be possible to separate out the engineers' share of each of the above subjects and give the responsibility for it to an engineer member of the Council? It would be quite impossible. The training of engineers must be the responsibility of the General Staff who direct the training of the rest of the army. Engineer work in the field is part of the general operations and must be the responsibility of the same body as the rest of the operations—again the General Staff. The recruiting and organization of engineers cannot be separated from the recruiting and organization of the rest of the Army. Railway work is transportation and cannot be run by a different authority from the one who arranges for shipping transport and road transport; they all form a single problem. This idea of separating the engineers and their work from the rest of the army is an impossible one, and the notion of having a head of the engineers on the Army Council is one that would cut across the whole principle on which the War Office is organized. So far from it being desirable to separate the engineers and their work from the army, what is really wanted is to bring them more into it—they are too much separated already.

But, it may be argued, if each branch of the War Office is to deal with the engineer work pertaining to it, does it not require competent technical advice? Yes it does, and in most cases it has got it. The M.G.O. has an engineer directorate to deal with the works for which he is responsible, the Q.M.G. has a branch, staffed by engineer officers, to deal with railways. The A.G. has an engineer branch, the General Staff has engineers forming a map production branch. There is, however, one extremely important branch of

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engineer activities for which no machinery exists for getting competent technical advice. For the training of engineers, both by themselves and in co-operation with the other arms, for the organization of their work in the field, for the consideration of the engineering requirements for any given plan of operations, there is no branch whose duty it is to provide the General Staff with technical engineer advice. This is the point where there is a blank in the existing organization.

What is wanted, however, is not a head of the Corps but an engineer adviser affiliated to the General Staff. A senior and experienced officer in that position would be able to advise the General Staff on all the above matters, on the compilation of training manuals, on the preparation of the engineering part of schemes of operations. He could frequently visit engineer units, explaining and expounding as necessary any points in the staff doctrines which he found were not understood and similarly acting as a 'liaison' channel by which any difficulties or wants on the part of units could be made known to the General Staff at the War Office; he would also see that technical and other training was being conducted on right lines and act as liaison officer on matters of engineering training with local Commanders, Staffs and Chief Engineers. Such an organization would dovetail into the War Office organisation and correspond to the organization authorized for war.

Why have we not got such an organization? Well, it has to be remembered that the engineers are not the only branch that requires it. Most, if not all the other arms—certainly all the technical ones—want it also, and to provide an advisory (or, as it is sometimes called, an inspectorate) branch for all of them would cost a lot of money, and money is tight in these days. The principle of having such branches has been recognised, and in the case of some of them, namely, the artillery, the tanks and the air defence branch, they have been established. It may be hoped that in due course the need for it for field engineer units and their work will be considered as sufficient to justify the expense.

Lastly, I would like to say this: There may be some who do not agree that the theory I have been expounding as to the position of engineers in the army organization is a sound one. As I have said, it has been for many years an indeterminate question and a subject of controversy, and many have from their own experience formed opinions on it which they find it difficult to abandon. But when an army policy, or an army organization, has at last crystallised out and has been accepted and formulated, then the time has come when it becomes necessary for us to subordinate our individual ideas, and our individualistic modes of thought, to the larger conception—the group mind of the Army.

Original thought is an admirable thing, and without it neither

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an army nor any other organization can progress. But there comes a stage when original thought must give way to *disciplined* thought. We have now got to that stage. After much discussion, in which original thought has had full play, we have now got the considered decision of the Army Council embodied in the regulations. It is the official and the only authoritative doctrine, and the contrary views to which I have referred in the course of this lecture must now be regarded as heresy. Whether we agree or not with the official doctrine it is our plain duty to accept it loyally, and to do our best, when the occasion arises, to make it a success.

We have got in fact to do, what sometimes men of original minds are apt to forget, that is, to get into the boat with the rest of the Army, to remember we are only part of the crew, and must conform to the stroke, and not persist in trying to row in our own individual time.

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"THE MAINTENANCE OF THE OBJECTIVE."

By BREVET-COLONEL W. G. S. DOBBIE, C.M.G., D.S.O.

"He that wavereth is like a wave of the sea, driven with the wind and tossed. Let not that man think that he shall receive anything. . . ."—*St. James.*

It must be admitted that the above words are true, not only in the special connection in which they were written, but also in all departments of life and not least in the domain of Military Science. The underlying truth of this maxim has many synonyms. It is sometimes described as the "single eye"—or as the impossibility of serving two masters. The modern military counterpart is the first "Principle of War" as enunciated in *Field Service Regulations*, and is styled "The Maintenance of the Objective." It will be seen that this principle is no new discovery of a modern military writer. It is as old as history and has always been recognised as being of vital importance, albeit, as will be shown later, it has frequently been disregarded.

That this principle is of the greatest importance is evidenced by the position of honour given to it among the other principles of war, and this fact is acknowledged by all military writers and thinkers. It is important not only in the strategical domain, but in the tactical as well. It applies to the smallest operation of war as much as to the biggest—to the nation as well as the platoon. Success cannot be attained if this principle is flouted, and its neglect may well spell disaster.

It must also be recognised that this principle which is so easy to enunciate, is evidently, judging by history, very difficult to carry out. There are innumerable instances of its disregard by commanders of all calibres. It is one thing to theorise on the principle, but quite another thing to apply it to the actual circumstances of a concrete situation, a lesson which has been learned in the hard school of experience by many.

All these considerations point to the necessity of all officers, of whatever rank or appointment, making a careful study of the matter, so that we may profit by the mistakes of others and thus avoid the danger of falling into the same pitfalls. A proper appreciation of the true meaning of this principle will also assist us to make the right decision in difficult circumstances, as it will enable us to separate essentials from non-essentials.

If we are to carry out the spirit of the first "principle of war." two things are necessary:—

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(*a*) We must be quite clear as to what our object really is, and
(*b*) Having decided on our object, we must not allow ourselves to be deflected from its pursuit by anything whatsoever.

It is proposed to consider these two points separately and to deduce from history or otherwise such lessons as will help us to put the principle into practice.

As regards the first problem, viz., deciding what the object really is, it is extraordinary how often disaster can be traced to failure here. If we are not absolutely clear about the object we have in view, confusion of thought and wavering of determination will result. Hence the paramount importance of seeing the object clearly, and keeping it constantly in view. Too often the "object" is confused with the means to attain it, a state of affairs which leads to the fatal mistake of pre-judging the question when the plan is being considered. It is, therefore, of the very greatest inportance that before considering the plan of action we should be absolutely clear in our own minds as to what the "object" in view is. If this is correctly assessed the difficulty in deciding between the various possible courses of action is automatically removed, or at any rate greatly reduced. In war a commander can have, or should have, only one object at any given time. In the case of a subordinate commander the object for him will be defined by the orders he has received from his superior, and will, generally speaking, be different in nature and in degree to the object kept in view by the superior. In other words, the object of a subordinate is in reality one of the means to attain the object of the superior. It is probably much more immediate in its application and does not look so far ahead. Putting it the other way, the course of action decided on by a superior as the best means of attaining his object becomes, through the medium of orders, the "object" of his subordinate commanders. These objects, though differing among themselves all tend to the one end. The Army commander and the platoon commanders all have widely different objects—but they are all working toward the same goal, provided that each is clear as to the part he has to play, and that the task of each unit has been co-ordinated by the mind guiding the whole, viz.: the mind of the superior commander. The problem for junior commanders as already hinted is usually fairly simple. Their "object" is given to them by their superior in the form of a definite order couched in exact terms, which admit of no misunderstanding or latitude. They have simply to devote all their energies to carrying out the orders they have received, and so long as the circumstances have not changed, the problem of deciding on their object presents but little difficulty.

As pointed out above, the "object" of a subordinate is generally defined by the orders received from his superior. This, however,

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is only true so long as the circumstances prevailing when the superior gave his orders remain unaltered. Should the circumstances have radically changed, the subordinate must ask himself what orders he would have received from his superior had the latter known or anticipated the new conditions. Thus the "object" for the subordinate has to be reviewed afresh and decided on by him in this light. This process will require deep thought, especially when the superior cannot be communicated with, but the care expended on deciding on the new object will be amply repaid by facilitating the choice of a course of action. In the case of higher commanders the orders they receive have of necessity to be framed in more general terms, leaving more latitude as to the definition of the object. But whether this definition is easy or difficult, the air can usually be cleared by the commander asking himself some simple question, such as "What is my *raison d'etre?*" "Why am I here?" The very simplicity of such questions is frequently the cause of their being overlooked, and yet they are the essence of the whole art of war. It is necessary to turn one's eyes away from the immediate surroundings, with all their bewildering confusion, and view the goal set before one, so that at the outset of the operation a true course may be set. But it is not only necessary at the commencement of an operation to assess correctly the object in view—it is also essential to keep it constantly in view throughout the course of the operation. There are numerous instances of operations having been initiated with the true object in view, but this has gradually been lost sight of and has almost insensibly been replaced by a totally different one. At first the deviation from the true course may be so minute as to be almost imperceptible—but gradually it becomes more pronounced. Local circumstances and conditions have assumed an undue importance and have distracted the attention from the real reason for the undertaking of the operation. A new object comes into being, and makes demands on the available resources which prejudice the attainment of the original and true object. This would all be avoided if the commander in question were to remind himself constantly of the real object which he set out to attain.

The origin of the deviation from the true course has been shown to be very subtle. Sometimes the suggestion has been made:—"Now that we are here, we might as well go on to . . . . , or do this or that thing? It will not need a great addition to our force, and it would be so useful. It would be a thousand pities, and so unenterprising of us, if we were not to take advantage of the favourable position in which we are placed to prosecute this further enterprise." How often have those arguments been put forward and how difficult it has often been to detect the fallacy underlying them! The consequence has frequently been that the commander

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concerned has been drawn on and on. His requirements have constantly grown. An increasing strain has been imposed on the available resources, which have had to be diverted from their proper employment, and the plans of the superior commander have been rendered ineffective owing to the lack of means to carry them out.

It is, however, not desired to deprecate enterprise and initiative, but to show that since the nation or any part of its forces is only capable of a certain amount of effort, it is most desirable that *all* the available effort shall be directed towards the desired end. All other effort is wasted, however attractive the scheme in question may be, and no force can afford this waste. It is a luxury beyond our means.

It must be realised that this truth applies to small affairs of tactics as well as to major strategical conceptions. The principle holds good for the platoon as well as for the Army Group. It, therefore, has its meaning for all of us irrespective of rank or appointment. A force composed of individuals who have thoroughly grasped this principle will be capable of almost anything, as effort will be economised and not wasted and will all be tending irresistibly toward one end.

It has been pointed out that a commander should only have *one* object. That is to say, that he should only receive from his superior orders to do one thing at a time. Dual duties are usually conflicting; they mutually interfere with each other. To take a simple illustration, one body of cavalry should not be ordered to carry out a particular reconnaissance and at the same time to screen the main body. The two things are conflicting, and attempts to do both may well lead to success in neither. The same principle applies equally on a bigger scale. An expeditionary force is landed to protect certain vital interests for the prosecution of the war, *e.g.*, the Persian oil fields. If that is the object of the Expedition, let it be clearly laid down. But if the additional object of, say, threatening Baghdad is superimposed, either by letter, word or even implication, the commander is placed at a grave disadvantage. The conflicting interests pull different ways—the force required to achieve the one object differs essentially from that required for the other—the first object hampers him in the execution of the second, and at best he becomes committed to an expedition far larger than was intended, and the principle of economy of force is shattered.

It may be useful at this stage to refer to one or two examples from history of the neglect of this principle. The great German plan for the attack on France is a case in point. Originally the whole essence of the German plan was an overwhelmingly strong right wing, which was to sweep irresistibly through Belgium and outflank the French left. The rest of the German forces deployed

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between this right wing and the Swiss frontier were to have a role entirely subsidiary to this great mass of manœuvre. Such was the conception of the author of the plan. His successor, however, allowed the plan to be whittled down in some vital points. Pressure was brought to bear on him to strengthen the left wing with a view to covering Alsace. Troops were taken from the right wing for this purpose. Again it was considered advisable to strengthen the force on the Russian frontier. It was the right wing again that had to find these troops. The result was that the preponderance of the right wing was greatly diminished and the success of the original plan altogether prevented. The original object had been lost sight of.

Another instance is supplied by the great German offensive of the spring of 1918. In March this offensive was launched against the right of the British line with a view to driving a wedge between the British and French Armies and thus separating the Allies. After the first impulse was exhausted and further progress was temporarily held up, the Germans launched another offensive against the Lys sector. It is necessary to be perfectly clear about the original purpose of this second offensive, in order that the after events may be correctly weighed. There seems to be no doubt that this offensive was undertaken as a subsidiary operation in order to assist the main operation towards Amiens. It was intended to draw our attention and reserves away from our right flank to the threatened area further north. Ludendorff, in his memoirs, when discussing the preparations for the German offensive of 1918, uses the word "feint" in connection with this northern attack. What actually happened? The German attack achieved considerably more success than was anticipated, and it would seem that this success led the German Higher Command to attempt to turn the subsidiary operation into a primary one, and to lose sight of the true object. This battle, or the "Bataille du Nord," as Marshal Foch used to refer to it, absorbed more and more of the German energies and resources, so that sufficient troops were no longer forthcoming for developing and extending the initial success at the decisive point. The final German attack toward Amiens took place on the 24th April. It all but succeeded. If they could have delivered a heavier blow then, the result might have been disastrous to the Allies. The error cost the Germans dear. It may be said, without exaggeration, that it lost them the war.

The foregoing considerations clearly show the importance of the "maintenance of the objective," and the disastrous results when this principle has been ignored. It must be recognised that the problem to be solved is often presented in an extremely complex fashion so that the big underlying and fundamental verities are not easily recognised. It is frequently very difficult to see the

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wood for the trees, and, this being so, it is of the greatest importance that officers should train themselves to pick out the essential points from a mass of unimportant and irrelevant though specious considerations. And this training should be insisted on in small matters as well as in big. It is the habit one wants to cultivate of separating essentials from non-essentials.

In the higher domain of strategy, and to a lesser extent in the sphere of tactics, political considerations arise to confuse the military problem. It would be out of place here to discuss the relation between politics and strategy—but it is important to realise how this element increases the difficulty of the military commander in solving his problem, and confuses the issue. What must be grasped is, that when once the military commander has been given his objective (and in the choice of the objective all political, economic and other relevant considerations have been taken into account), he must not allow himself to be diverted from its pursuit. As Clausewitz says :—" He who would yield to these impressions (outside influences), would never carry out an undertaking, and on that account perseverance in the proposed object, as long as there is no decided reason against it, is a most necessary counterpoise."

The problem sometimes presents itself in the guise of a suggested " detachment " or " diversion." These enterprises can be made to appear most attractive and alluring, and one is very easily drawn into a false position. One finds oneself weighing many and various considerations, and becoming more and more undecided as to the best course of action to pursue. The consideration of the object however, should lead one to a rapid and correct solution of the problem, and save one from being affected by these cross currents and complex arguments.

Diversions are suggested for a variety of reasons. Those who are uneducated in a military sense frequently look upon them as a short cut to success. They think that the direct road can only be forced by severe fighting, and, therefore, they argue that they are following the principle of " economy of force," if they try to go round by a road where the difficulties are less, irrespective of whether the new road leads to the desired goal or not. It is as if a motorist were to select a road merely for its surface and gradients and without regard to where the road leads to.

Again, they are sometimes suggested as offering a chance of an immediate success. It is urged, perhaps, that it is most important for political reasons to be able to announce a victory. The military commander must, however, be very careful to take the long view rather than the short view. He must consider the effect of the proposed operation on the final success of the cause. A local and immediate success will be of little value if it spoils the chance

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of final victory, and it is this aspect that it is the duty of the military commander to scrutinize most carefully. In other words, he must keep the " big " object in view and judge every suggested enterprise by its effect on the main plan. As a matter of fact, the very name " diversion " should make one treat them with suspicion. The name suggests a deviation from the true course, and in considering the advisability of a diversion, one must repeatedly and definitely bring before one's mind the " object " one is striving to attain. If one is quite clear as to the object, it is not difficult to decide on the desirability or the reverse of the diversion or detachment. The matter is really quite simple. If the diversion helps toward the attainment of the " object," it is justified ; if not, it is not justified. Defined in this way, the decision appears to be very easy, but it is extraordinary how complex it often seems to be. So many conflicting considerations are advanced—political, economic and military. It is impossible to reduce these considerations to one common denominator, so as to decide the relative value of each, and weigh one against another. One cannot arrive at a conclusion that way, but, fortunately, the matter can be decided by an answer to the question " Does this enterprise assist the attainment of my true object ? " That is a question which can usually be answered without difficulty, and its answer solves the problem. This goes to prove, as has already been pointed out, the importance of deciding on the " object " before considering the plan of action, and that energy expended for this purpose is very well spent.

It forms an interesting study, to examine the diversions and " side shows " undertaken by this country at various times in her history, in this light, and to apply this test to them.

To sum up—the following lessons stand out as being of vital importance to all military commanders in the conduct of operations however large or small :—

(*a*) Be sure you are quite clear as to the object you have in view.

(*b*) During the course of the operations constantly review your action in the light of this object, and make quite sure your course is still heading in the right direction.

(*c*) Bring every suggested enterprise to this test :—" Will it assist me in the attainment of my object ? "

An officer whose conduct is dominated by these principles will not go far wrong.

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THE EARLY YEARS OF THE ORDNANCE SURVEY.

(Continued.)

VI. Progress from 1820 to 1825.

Drummond, Gardner, Dawson.

Progress of the Survey, 1820-25.—In 1824 a Select Committee of the House of Commons, under the chairmanship of Mr. Spring Rice, was appointed to consider the question of a Survey and Valuation of Ireland, and Colby, as Director of the British Survey, gave evidence in March and April of that year. The Ordnance Survey had now been in official existence for thirty-three years, and it appears from Colby's evidence that the triangulation of Great Britain was nearly completed, though it must be noted that many of the stations were subsequently revisited: the latest observations were not made, in fact, until 1853, and most of the angles in Great Britain, used in Clarke's reduction, were observed after 1837. Colby stated that the one-inch map of England and Wales was two-thirds completed in the field. The one-inch map of Scotland had not been begun.

Some of the questions and answers are interesting, for instance :—

" [The Survey of England] was begun upon six inches to a mile? Part of Kent, which was considered of consequence for military purposes, was surveyed upon that scale.

" It was actually protracted upon that scale?—Yes.

" Are there any means now in existence of protracting the surveys you have made in England upon that scale?—No, certainly not; the survey has been made upon the scale of two inches to a mile.

" You could not now protract the survey of England from your field notes upon the scale of six inches to a mile?—Not with the degree of accuracy which that scale would require."

It may be noted that the Committee made use of the term Ordnance Survey, thus: "In the ordnance survey do you distinguish the different descriptions of roads?"

As regards the strength of the department in 1824: "What is the force employed in England and Scotland now?—We have ten officers of Engineers.

" What force have you under them; what is the whole force employed in the survey?—I have ten surveyors under them.

" Is that the whole force?—Yes, the whole force."

It may be supposed that we should add to this number the engravers at the Tower. In the draft of a minute to the Board, written probably by Colby about 1820, it is stated that Mr. Baker

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was the principal engraver, and there were three apprentices who were engaged because "much difficulty had been found in procuring a sufficient number of persons already initiated in the art of engraving who were accustomed to the style of accuracy required in the maps." How many other engravers were employed at the Tower is not known. On completion of his apprenticeship, an engraver was paid £2 12s. 6d. a week.

The Peace of 1815 had freed officers for this employment. Lieut. Richard Mudge was appointed to the Survey in 1816; then followed Lieuts. Dawson, Robe, Renny, Captain Gossett and Captain Vetch, in 1819; Lieut. Drummond in 1820 and Lieut. Larcom in 1824.

It is sometimes supposed that, in 1825, the whole personnel of the Survey was transferred to Ireland. Sir Henry James, who was then Director of the Survey, stated in 1859, that, in 1824, the one-inch survey had extended from the Land's End to the boundary of Yorkshire and Lancashire, including the whole of Wales. He went on to say that, "it was then decided that there should be a general valuation of Ireland, and that as a necessary basis for that valuation, there should be a town land survey. . . The whole survey force was then sent to Ireland, and the survey of Great Britain was altogether suspended. We commenced first in the North of Ireland, I myself taking part in the survey."

But this was not quite the case. The office in the Tower was still kept in existence, and some field work was still carried on, in order to keep the engravers at the Tower supplied with material for the one-inch map. Colby was frequently at the Tower. It would appear to be more correct to say that most of the officers and men were transferred to Ireland in 1825, leaving only Captain Mudge in the Tower with a very small staff to deal with the one-inch sheets of England and Wales.

In December, 1822, there came a visitor to the Survey Office in the Tower, whose name is very familiar to most British topographers, namely, Robert Shortrede. All who have painfully interpolated the logarithms of trigonometrical functions, in the absence of their copy of Shortrede, will always recall his name with gratitude, and swear never to go without him again. On the 22nd December, Robert Stevenson, the engineer, wrote the following note to Colby:—"The bearer, Mr. Robert Shortrede, was for some time in my office and now goes to India under the auspices of Sir Walter Scott. He is a very keen mathematician, and I beg to be allowed to give him an opportunity of seeing the extent of the trigonometrical survey in the Drawing Room."

Robert Stevenson, the writer of the note, is justly celebrated as the designer and builder of many lighthouses, notably that on the Bell Rock. But he is, nowadays, even more celebrated as the grandfather of R. L. Stevenson, who was, however, born after

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his grandfather's death. In the Colby collection there are many letters from Robert Stevenson, who frequently corresponded with Colby. The little letter above quoted brings into pleasant juxtaposition the names of Sir Walter Scott, Stevenson, Shortrede and Colby—literature, lighthouses and logarithms.

In January, 1823, died that old mentor and friend of the Survey, Dr. Charles Hutton. His son wrote to Colby from 34, Southampton Row, on the 29th of that month :—

" It is my painful task to inform you that my venerable Parent, your Friend, Dr. Hutton, departed this life on Monday morning, after an illness of several weeks, in the 86th year of his age. It will be pleasing to his numerous friends to learn that he happily retained his mental faculties to the last. So recently as Friday afternoon, he dictated a letter, in reply to a communication which he had received in the morning, soliciting the favor of his opinion as to the form of the Arches, which it would be most advisable to adopt, in the construction of the Bridge proposed to be erected over the Thames, on the removal of the old London Bridge."

The Survey owed much to Dr. Hutton, who advised the Duke of Richmond to appoint Mudge, and the Duke of Wellington to appoint Colby. It is true that he advised the appointment also of the ineffective Williams ; but, fortunately, no great harm was done, and Hutton could hardly have foreseen that Williams would be a failure.

Dawson, Robe, Renny, Gossett, Vetch, Drummond and Larcom, with Henderson, Murphy, Portlock and James, were all employed on the Irish Survey in the early days. The outstanding men amongst them being Drummond, Larcom and James. Of Larcom and James we shall hear later on, but this may be a convenient place for a brief sketch of Drummond's career.

Thomas Drummond.—Drummond was born in Edinburgh in 1797, and, after passing through the R.M. Acadamy, was commissioned in the Royal Engineers in 1815. In 1820 he was posted to the Ordnance Survey and remained on that duty until 1831. " During his winters in London he attended the lectures of Professor W. T. Brand and Michael Faraday at the Royal Institution, and the mention at one of them of the brilliant luminosity of lime when incandescent, suggested to him the employment of the limelight for making distant surveying stations visible. In 1825, when he was assisting Colby in the Irish Survey, his lime-light apparatus (*Drummond light*) was put to a practical test, and enabled observations to be completed between Divis Mountain, near Belfast, and Slieve Snaght, a distance of 67 miles."*

Trials were also made in the " long room " of the Ordnance Office in the Tower, a room which is stated to have had a length of 300 ft.

* *Encyclopædia Britannica. Art. Thomas Drummond.*

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The block of buildings of which it formed part was burnt down in 1841. Sir John Herschel thus describes the impression produced when the lime-light was shown on this occasion :—" The common Argand burner and parabolic reflector of a British lighthouse were first exhibited, the room being darkened, and with considerable effect. Fresnel's superb lamp was next disclosed, at whose superior effect the other seemed to dwindle, and showed in a manner quite subordinate. But when the gas began to play, the lime being brought now to its full ignition and the screen suddenly removed, a glare shone forth overpowering, and as it were annihilating both its predecessors. . . . A shout of triumph and of admiration burst from all present." *

In a letter from Colby to his wife, written from the Tower, May 28th, 1830, he says: " To-morrow I go to the visitation at the Royal Observatory, and on Monday we have another exhibition of Drummond's light. We expect Lord Melville, Sir George Cockburn, Sir Thomas Hardy, etc., to be there with the Trinity Board. The last exhibition was quite triumphant. We had a strong shadow by holding the finger before a piece of white paper though the light was 10 miles off !"

This light was first used in practice for the 67 mile ray between Divis and Slieve Snaght; Drummond was in charge of his light on the latter mountain, which is in Donegal and is over 2,000 ft. high. The party did not begin operations until the end of October, 1825; the season was late, and the weather was bitter. Drummond writes from Slieve Snaght on the 28th October: " The tent is now up and in a few minutes the wall round it will be completed, so that we may consider ourselves safe against any storm; the wind has, fortunately, been Moderate, the fog still continues." Drummond was also using a heliotrope invented by himself. On the 4th November he writes: " This Morning about 9 a.m. the weather cleared, the sun broke out, and I gave you instantly a reflection which kept up till 2.13—with several eclipses intervening. A storm of snow came on at that hour. . . I am just going to make preparations for the camp. . . My tent is blown [down] and I now write from a kind of Cave, formed on the lee side of the Hill. Shall commence with the lamp at ¼ past seven."

Drummond suffered much from wind, cold and fog at varying intervals. The tents were sometimes blown down, and it was only with great difficulty that it was possible to direct the light to Divis at night. " The wind encreased to a gale and a sweeping Shower of rain passed over the Mountain. . . What a Villainous Climate. If this evening proves at all possible I shall blaze away till ½ before 11. . . ¼ past seven is my first appearance."

* *Dictionary of National Biography. Art. Thomas Drummond.*

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On November 5th, writing to Murphy, on Divis : " Give me credit for doing all I can and be thankful for what you get." On the 8th : " Yesterday proved an impossible day. . . Squall succeeded Squall."

On the 9th things were better : " This day promises well ; at 9.18 a.m. the first reflection commenced and Mr. Larcom is now at work—sun bright. . . If this day holds you shall have the lamp every appointed time and I trust our labours will be finished." On the 10th : " I forward you the account of our operations yesterday—if not successful—I despair of success ; there must be a hill in the way."

The operations were successful ; there was no hill in the way. But Drummond did not know this for two or three days. On the 11th at 3 a.m. he writes : " The poor devil who went for the letters has been wandering on the hills since 5 in the evening. . . I look for to-morrow's letters with much anxiety." On 12th November, 1825 : " Of the successful termination of our labours the letters from Divis will already have apprized you. . . . At the last we had nothing remaining but the lamp tent and the walls of the Cooking House. I believe that we should have been compelled to abandon the hill but for the efforts of the men. . . I subjoin a list. . . Corporals Williams, McLaren, Moulton and 9 privates." From Belfast on the 19th : " I arrived here yesterday from my Snaught expedition."

On 12th Lieut. Henderson writes from Divis :—

" On Wednesday I gave you a very hurried intimation of our having seen the reflector. I have still greater pleasure in communicating the result of the light, it was most brilliant. . In the evening, when preparing for our observations, one of the watch called out that there was a much stronger light than the one at Randalstown and a little above it ; we immediately turned to that direction and we there saw the light ; it was most brilliant, exceeding in intensity any of the Light Houses. . . . These two days' observations have completely established the advantage of this admirable invention . . . the light . . . can be very easily intersected from its steadiness and brilliancy. . . At night the light was observed on one arc and reverse ; it was taken with all the Light Houses from Corsil to the Lower Light House on the Calf of Man.—Lt. Henderson, Observer."

On the 13th, Henderson writes from Divis :—

" It was most fortunate that the reflector and light were seen on the two days, as since that the weather has completely changed, so much so that yesterday it was with difficulty the places to mark the station by could be seen. Everything is now arranged and to-morrow [we] commence taking down the observatory tent and prepare for the staff and pile.

All those of us who have waited patiently on inhospitable hills, for the glimpse of a ray of light from a distant trigonometrical point, will sympathise with Colby, Murphy and Henderson on Divis ;

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and still more with Drummond and Larcom on Slieve Snaght, for they were uncertain up to the last as to whether their labours had been successful. One says to oneself sometimes: "It's a dog's life—but it has great compensations."

In June, 1830, Colby writes: "Lt. Drummond is trying for a situation and is pretty well supported." The "situation" was in connection with the great Reform Bill; Drummond was, in 1831, appointed head of the Boundary Commission, which was necessary for laying down the new electoral areas. In 1833 he became Private Secretary to Lord Althorp, Chancellor of the Exchequer; and in 1835 he was appointed Under-Secretary for Ireland.

Neither the Lord-Lieutenant nor the Secretary, Lord Morpeth, took an active share in the administration of the country, and Drummond found himself the Governor of Ireland. There was, thus, a great change in the relative positions of Colby and Drummond; from being an officer on the Survey under Colby, Drummond became the ruler of the country which Colby was surveying; and it was, perhaps, inevitable that the situation should be a somewhat difficult one for Colby; though it must be remembered that the Survey was under the Ordnance and not under the Irish Government.

Some years later Colby writes to his wife: "I have doubts of Drummond having really committed himself by the observations attributed to him. He is incautious, but such observations are not like what he would have made on any subject when under me. However, I do not excuse him for not having written to me before he acted." And again on February 8th, 1840:—

"Lord Morpeth's letter was perfectly gentlemanlike and friendly to the Survey—but Drummond's was the most intemperate and offensive attack on the Survey you can possibly conceive. It fortunately happened that his zeal to injure the Survey carried him into a good many sheets of writing, and when there is great length and great bitterness, there is always room for a reply. I was, therefore, enabled clearly to establish his error quite to the satisfaction of the Master General on every essential point."

The particular cause of their dispute was the execution of the geological survey as an adjunct to the ordnance survey—the former being included in the term "matters of mere curiousity" by a subordinate of the Board. But the Master-General stood by Colby; the Master-General, indeed, was not a little annoyed at receiving "a most impertinent letter from a Captain of your Corps, who because he is Secretary for Ireland takes upon himself to be insolent to the Ordnance.'

It is to be regretted that the relations between Colby and Drummond were strained over this matter of the geology of Ireland, for Drummond had done good work for the Survey, and he died two months after the letter last quoted was written—worn out by overwork. He left the reputation of a real friend of the people

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CAPTAIN THOMAS DRUMMOND, Royal Engineers.
Under-Secretary to the Lord Lieutenant of Ireland, 1841.

From an engraving presented to the R.E. Museum by Brig. Gen. E. M. Paul, C.B., C.B.E.

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of Ireland; "moved by the miseries of the people, touched by the injuries to which they were being subjected, and pained by the evidence of misrule which everywhere met his eye."* It was he who told the Irish landlords that "property has its duties as well as its rights." O'Connell, convinced of his goodwill to the country, supported him.

Perhaps his chief administrative act was the foundation of that fine body the Royal Irish Constabulary, but no side of the administration was neglected by him. The continuous and overwhelming work, and the difficulties that he had to contend with, told rapidly on his health, and he died on the 15th April, 1840. It is not often that a man, who has distinguished himself in a technical sphere, becomes equally eminent in that of government; and Drummond, who had that double distinction, may properly be regarded as one of the most talented officers who have ever served in the Army.

Before giving an outline of Colby's career, it will be right to describe, very briefly, the lives of two officials of the Survey, who carried out much useful work under Mudge and Colby. Their names appear frequently in the accounts of the Trigonometrical Survey and in the technical correspondence of the period. These two officials are James Gardner and Robert Dawson.

James Gardner.—An important member of the Survey staff, during the whole of Mudge's directorate and later, was James Gardner, who, apparently, before the formal establishment of the department, was the "chief draughtsman" of the Board of Ordnance at the Tower. He was probably posted, as a Warrant Officer, to the Corps of Surveyors and Draughtsmen, in 1802. But it is not in connection with drawing that we usually find his name mentioned, but almost always with observing. It is recorded that he observed with the large theodolites at thirty-eight stations. The last stations he observed at being the cross-channel group, at which angles were re-observed in 1822, viz.: Crowborough, Fairlight, Folkestone, etc. He also assisted in the observations with Ramsden's zenith sector at Kellie Law, Cowhythe, Balta, and at Dunkirk across the water. And from the very commencement of the one-inch map he was constantly employed in fixing minor points for the "interior survey," as Mudge mentions in the accounts for 1791 to 1795.

We do not know much about him, except that he appears to have been a very efficient observer, who was connected with the survey for thirty years or so. But five letters from him to Colby have been preserved, and a few extracts from these may serve to give some information with regard to the personality of this old public servant.

* *Dictionary of National Biography.*

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From Edinburgh, 31st May, 1816 :—

" I am glad to inform you that after watching night and day I have at length succeeded in catching the Dunrich hill, having got nine observations, seven of which agree remarkably well. To-day I expect to have the tenth Western elongation. . . I have not since you left seen further to the westward than the Orchills, and the only thing done in that quarter is taking the Camproys twice—Meridian marks are not so easily placed as I imagined."

He mentions the difficulty he had in getting permission to cut down a few trees that obstructed the rays :—

" A shrub in the neighbourhood of Falkland is as much thought of as the largest oak in Sherwood Forest."

" I have given the Woolwich party [of R.A.] money to buy shoes and shirts, and taken care that they have done so. At Woolwich they imagined perhaps that as the men were to get to Scotland, the nearer approximation to nudity they would the more easily pass for Scotchmen."

From Lincoln, 30th December, 1818 :—

" I have at length succeeded in getting points for Mr. Metcalf and Mr. Budgen. I am now at work in Mr. Stevens' district, and if the weather permits, shall have a stiffening of points for him by the end of next week, when I shall return to town unless I receive orders to the contrary. . . . I am sorry I did not take your advice and wait till spring. I never suffered so much fatigue and cold in my life. Glush Mull is a paradise compared to Lincolnshire at this season of the year; we have been out several times till 10 and 11 o'clock at night, on account of thick fogs and bad roads, and when I return I shall be happy at the *novelty* of dry feet."

In another letter he sends his " best respects to Mr. Robe, Mr. Drummond and Mr. Dawson."

Wallingford, 18th November, 1821 :—

" I have just completed a week's work, but what with bad weather, short days, and roads almost impassable, the progress has not been such as I should have wished. Am sorry also to observe that I can derive but little advantage from Mr. Woolcott's work, not but that there is a good deal done, but the angles seem so roughly taken that it would be almost dangerous to incorporate them with anything that deserves the name of a trigonometrical survey, in some instances the great differences betwixt arcs arise from the clumsiness of the objects, many often clump objects at the distance of several miles have covered the field of view of my telescope ! ! ! . . The angles of Mr. Dawson's series seem to be very well taken; I shall obtain a base to verify his series direct almost from the great instrument."

The last letter preserved deals with the printing of the maps of the Survey of Ireland. This letter is dated Regent Street, 7th February, 1827. Gardner had been appointed agent, *i.e.*, map-seller, to the Board of Ordnance. The reasons for the appointment are described by Colby, in a minute from which the following paragraphs are abstracted. The subject of map sales is dull enough, but it affects the finance of the Survey and is one which continually

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recurs in its history. The matter was not satisfactorily settled until a few years ago.

Colby writes :—

" When I had the honour of receiving from the Duke of Wellington the appointment of Superintendent of the Survey in 1820, I found the sale of the maps carried on in two ways, the one by the principal engraver at the Office in the Tower, the other by Mr. Faden, the mapseller, at Charing Cross. A trade price and a selling price were established, but all those who came to the Tower received maps at the trade price, whilst those who purchased of Mr. Faden paid the selling price. The sale of the maps at the trade price to the public at the Tower irritated all the mapsellers against the Ordnance . . . and they most strenuously opposed the sale of the maps by every means in their power. . . On the 30th August, 1820, the Master General and Board were pleased to grant Mr. Faden an allowance of 10 per cent. to enable him to supply the rest of the trade. . . He received maps from the Tower on sale or return. . . Mr. Faden was not bound by any agreement to sell the Ordnance maps in preference to others."

This arrangement did not work well, largely because the discount allowed was too low.

" When Mr. Faden retired from business the Honourable Board entere into an agreement with Mr. James Gardner, who was well qualified as a geographer, to act as their agent. And he on the faith of his agreement purchased a house in Regent Street to carry on the sale of their maps, and bound himself down not to sell any other maps which would supersede them."

That is almost all that we know about James Gardner; but, perhaps, even less will be known about most of us a hundred years hence.

Robert Dawson.—The Survey was such a small department, in those days of the early nineteenth century, that the personality of each member of it counted for a good deal; and, happily, there were no failures amongst the five who, until 1916, were chiefly responsible, namely, Mudge, Colby, Woolcot, Gardner and Dawson. Robert Dawson was born in 1776 and, when he was eighteen, he was employed as a draughtsman under the Board of Ordnance, at a salary of £54 a year. The Corps of Royal Military Surveyors and Draughtsmen was formed in 1802, and consisted of warrant officers, selected for their skill in carrying out the " interior " survey. Amongst those appointed, on the formation of the corps, was Dawson. It appears that he had already been selected to instruct, in drawing and surveying, the officers intended for that branch of the Q.M.G.'s department which eventually became the Intelligence Division.

" To General Morse . . was due the very judicious idea of rendering this corps useful in instructing the young Engineer officers in sketching and surveying. . . At his request, General Mudge allowed Mr. Stanley

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and Mr. Dawson, two of the most able surveyors and draughtsmen of the corps, to undertake this task."*

The young officers were attached to the Survey and were sent to the field wherever Dawson happened to be working. When Addiscombe was established, in 1810, Mudge entrusted the field instruction of the cadets, in surveying and drawing, to Dawson. So that probably Dawson, more than any other man of his time, formed the ideas of the Army in this branch of military art.

It is said that :—

" Besides his other qualifications, Mr. Dawson had the merit of bringing topographical drawing to a degree of perfection that had given to his plans a beauty and accuracy of expression which some of our eminent artists had previously supposed unattainable."†

Portlock speaks of Dawson's great artistic talents. Some of Dawson's topographical drawings of the Welsh mountains are said to have been the finest ever produced. Two sheets of Dawson's hill drawings on the 2-inch scale (Snowdon and Cader Idris) are preserved at the Ordnance Survey Office, Southampton. Whilst it may be said that they do not, perhaps, deserve the unstinted praise given to them by contemporaries, they are, nevertheless, excellent examples of the art, and admirable guides for the engravers.‡

He died at Woodleigh Rectory, Devon, in 1860, aged eighty-four.

Some letters written by Dawson to Colby show that they were on very friendly terms. On the 6th February, 1812, he writes from Worcester :—

" I see you are within one step of a 1st Captain and hope to live to see you many steps above it, and as much my friend as ever, though the progress of rank may increase our distance."

In another letter he writes that Mudge has permitted him " to take his East India pupils and engage in a reconnoitring and sketching essay for their instruction, with the usual travelling allowance from the Company," into the mountains of North Wales. The party travelled sometimes on horseback, sometimes on foot, and sometimes by chaise. They surveyed with the compass (he writes in one of his letters about testing the variation of the compass), made " panorama views " and perspective sketches. He says that he has been so pressed to project his work that he had not even written to Colonel Mudge. In an undated letter he writes of " the gratification you must have felt in visiting the Quarter Master-General's office. The stone printing interests me much, and I should

* Portlock's *Memoir of Major-General Colby.*

† *Memoir of the Mudge Family*, p. 140.

‡ The portion of Dawson's drawing of the Snowdon district, here reproduced, hardly does justice to his skill, owing to the bad state of the paper. The date should be " about 1820," and not 1815, as printed.

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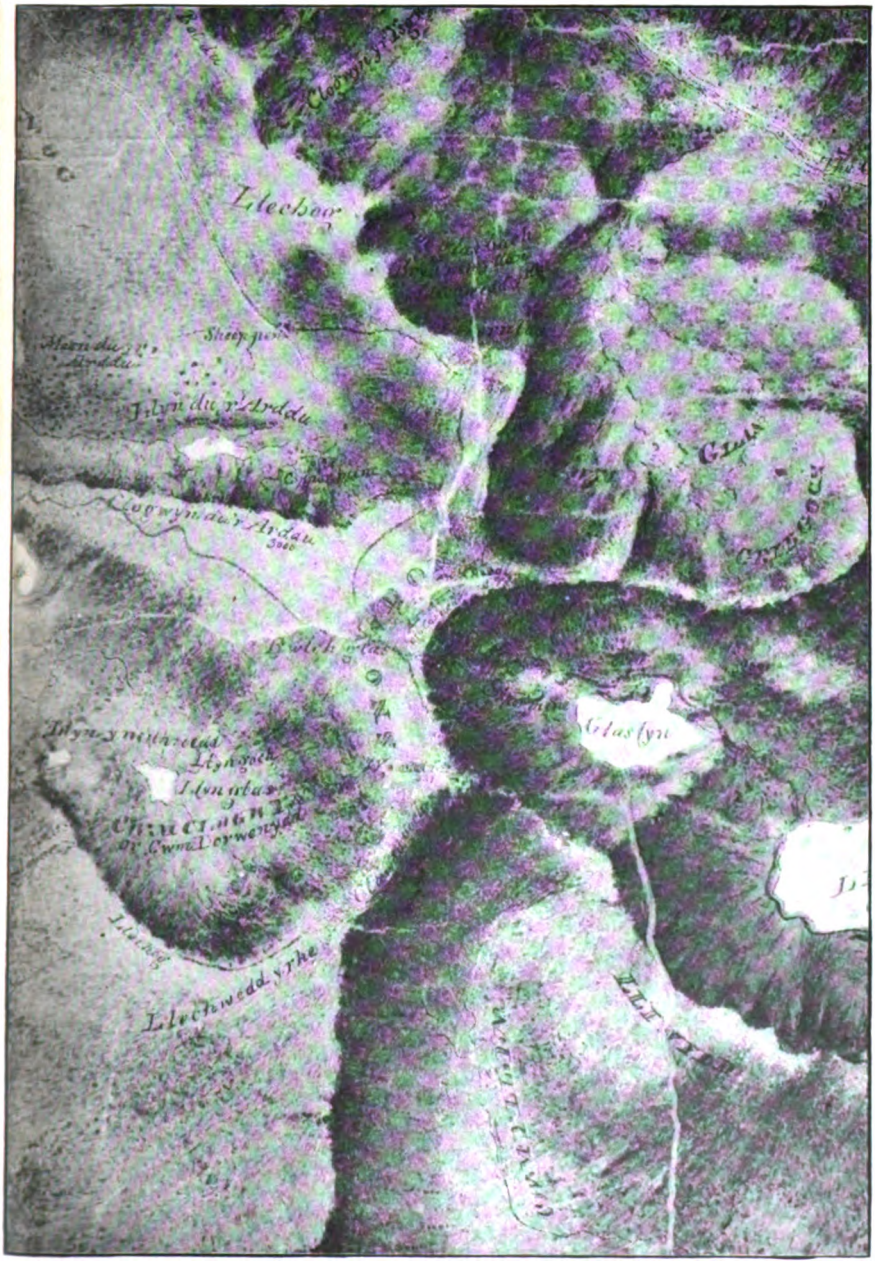
HILL DRAWING OF PART OF THE SNOWDON AREA.

By Robert Dawson, of the Ordnance Survey 1776-1860.

Drawn in the year 1815.



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like to try it of all things, for if it can be done with good definition and effect it must be an admirable contrivance."

In April, 1814, he writes from Shiffnal :—

" Perhaps you have seen the letter I sent yesterday with the Reports of the Candidates' Progress to Colonel Mudge. I fear that he will think it too severe. I wrote quick and meant to be just, and I believe was so, but I was certainly a good deal chafed with the friction I encounter in some of the young men—and besides a little bilious, and perhaps not a little splenetic from its effects. However, it is necessary that Colonel Mudge should know that these young men want some check from his hand. . . Mr. Blackiston is a very well bottomed young man, rather heavy, and his faculties not yet pointed. . . Would it be too much to ask, through Colonel Mudge, for a copy of Major Lambton's account of his trigonometrical survey in India. . . I think it might be useful to have it to shew to the E. India Cadets."

On the 8th December, 1815, from Lichfield :—

". . . May I not aim at a large and striking example of topography in my new Welsh work—and may not the Cader Idris plan be a sort of coup d'essai on the effect to be produced ? "

On the 14th of the same month :—

" Perhaps it will be best to have all the plans of the survey done in Indian ink for the future, and as near the effect of engraving as may be. . . Mrs. D. and myself were wishing last night that we could have the quiet leisurely comfort of your company once more, before a deluge of pupils comes upon us."

On the 8th January, 1816 :

" I have given a good deal of time to Cader Idris, which now is getting into something like its finished effect. . . It must necessarily be a long time before there are many competent judges of these particulars. . . The Geological Society has a direct tendency to increase intelligence and interests in the thing, and by its means it probably will be brought to a high pitch of improvement."

In 1824 he describes some of the officers whom he is instructing :—

" Mr. Durnford has hardly been long enough with me yet for his character to come out. I think he has good capabilities and does everything in a solid and accurate manner."

In the same year he complains that the Master-General will not give him a permanent position. Later on this was rectified. He found it hard work to get out of the Honourable Board the money due for surveying and correcting sheets ; the Board appears to have been always behindhand in payments :

" Allow me to beg you to not let the money be delayed for my surveying. I want it much, and shall be extremely obliged for your interference to hasten its payment." " I am very sorry to learn you have met with delay and objection in regard to the Contingent Bill," etc.

He kept up a correspondence with his Indian pupils :—

" W. N. Forbes . . poor fellow, had been extremely ill from the climate, but had struggled on, and got nearly thro' a very extensive survey of

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part of the Delta of the Ganges. Of Macleod we have twice heard lately and of his excursions on the Ghauts and with Sir John Hislop's Army. Oliphant has written me an account of his journey with the Madras Army," and so on.

Certainly Robert Dawson was an important member of the limited staff of the old Survey, and his letters give a very pleasant idea of his character.

Robert K. Dawson—his eldest son—was educated at the R.M.A., Woolwich, under Mudge. He was commissioned in the Royal Engineers in 1818, and was employed under Colby on the Ordnance Survey. He retired as a Lt.-Colonel and became head of the Survey Department of the Commons Enclosure and Copyhold Commission. He died in 1861, less than a year after his father. A few of his letters to Colby remain, mostly on technical subjects. In March, 1822 :—

" The churchwardens at Frant are a little annoyed at having your Gothic Pole on their modern edifice and wish it removed from their new church as soon as possible."

In the same month :—

" The sketching of Budgeon's work (in the neighbourhood of Sleaford particularly) is decidedly bad."

From Mull, 13th September, 1822 :—

" The observatory was taken down on Tuesday last and embarked at the small isles, where we were detained till Friday morning by a tremendous gale of wind, which if we had awaited it on the hill would certainly have sent us down without horses. We arrived here last night, and as the weather now appears to promise well we are compelled to make this a working day. . . Captain Melville [R.N.] is as usual rendering us great service."

On the 30th of the same month :—

" . . . Allow me, my dear sir, to offer you now my sincere thanks for your kind attention and consideration to my father—and particularly for your regulation, which secures to him the advantage of an assistant, for his health is now declining so fast." N.B.—The old gentleman lived for 38 years more.

In another letter he says :—

" Most happy shall I be to leave this gloomy hill [Jura]. As yet we have only on one occasion ventured more than a mile from this camp, and then the hill was covered from morning till night."

After the commencement of the Survey of Ireland, he writes from the Tower on 10th October, 1825 :—

" By the Liverpool Canal on Saturday we forwarded to Major Reid at Dublin six cases of instruments. . . The characteristics [*i.e.*, conventional signs] shall be sent in a Frank to-morrow."

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A SHORT ACCOUNT OF THE TRAVERSING OF A BUILDING AT DELHI.

By COLONEL J. ROBERTSON, District Engineer, East Indian Railway.

Under conditions existing prior to the carrying out of this work at the Delhi Main Station the road leading from Queen's Road to the Inward Parcel Office passed through the compound of the 3rd Class Waiting Hall at the east end of the Station, and was most inconvenient, enabling all and sundry to obtain access to the platforms. It was, therefore, decided to remove the existing latrine westward, so as to permit the approach road to the Inward Parcel Office to pass behind and between it and the Outward Parcel Office, thus enabling the compound of the 3rd Class Waiting Hall to be one circumscribed and bounded area.

On considering the best method of carrying out the work it appeared feasible to remove the 20-seated water borne latrine bodily from its original foundations to a new site, so as to give room for the approach road, without dismantling the building and erecting another, which it was hoped would prove a cheaper method, besides being an interesting engineering work and one which had not been previously attempted with a masonry building of this size in India.

The building, erected in 1918 (Plate No. 1), is 38-ft. long, 14-ft. wide and 17-ft. high above plinth, and is of first-class brickwork in lime mortar. The foundations were 3-ft. 6-in. deep.

The longitudinal walls comprise five Gothic arches of 6-ft. span on piers, the intervening spaces being filled in with 10-in. brickwork; the end walls have each three Gothic arches, two of 2-ft. 6-in. span and a central one of 3-ft. span, which latter are open and give access to the latrine.

Within there is a 10-in. cross wall, dividing the latrine for males and females from floor to roof and on each side of the central passage way partition walls 6-ft. high, dividing the building into compartments; these partition walls are of 5-in. brickwork plastered with cement and supported on light supplementary foundations, carried to a depth of 2-ft. 6-in. below floor level, and the walls are reinforced by a frame-work of old rails. Each compartment is fitted with a door of corrugated iron in an angle iron frame.

Longitudinally, on both sides of the building, run semi-circular E.W. channels, connecting in a master trap at the end of the building.

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Outside, the building has pillars, corbelling and cornice work, but the inside is absolutely plain with no projections; the floor of Indian patent stone on ash filling.

The total weight of the building is calculated approximately at 150 tons.

In order to shift the building it was necessary to divide it from the old foundations, which was done by inserting a frame of channel iron box girders below the plinth level (Plate II, Figs. 1, 2, 3 and 4).

For traversing, six compound rail joists (Plate III, Figs. 5 and 6) and the following additional material whose functions will be explained hereafter :—

1 Pair 1⅛-in. diameter tie rods 39-ft. long with turn buckles (Plate No. III, Fig. 7).
2 D.H. Scrap rails 15-ft. long.
6 Tie rods, 14-ft. 6-in. long, 1⅛-in. diameter with 6-in. x 6-in. x ½-in. washers at each end. (Plate III, Fig. 8.)
6 Sal Sleepers 12-in. x 6-in. x 11-ft.
5 Sal Sleepers 12-in. x 6-in. x 15-ft.
80 Firewood Deodar sleepers.
2 Pine baulks 14-in. x 14-in. x 25-ft.
6 Screw jacks of 10 tons lifting capacity.

PRELIMINARY ARRANGEMENTS.

The above materials, illustrated in Plates II and III, were prepared and the building carefully examined.

Two small cracks were detected in the roof, one of them laterally across the whole roof; across these were pasted paper tell-tales to enable the cracks to be watched, otherwise the building was sound.

New foundations were now built, identical with the old (Plate V); work was then started.

The top of the building was tied by means of tie-rods with turn-buckles longitudinally and rails at each end (Plate III, Fig. 7), the ties being tightened by means of the turn-buckles: above the position of the channel framing and 1-ft. above ground level, five transverse tie-rods were introduced with five Sal struts 12-in. x 6-in., to absorb tensile and compressive stresses (Plate III, Fig. 8). Special holes were drilled in the 10-in. walls for the tie rods, but the struts were driven tight with wedges to insure an even pressure and bearing.

Sleeper pieces 2-ft. long were introduced between the outside of the walls and the iron washers on the tie-rods.

The under pinning was now started.

One channel, 40-ft. long, was taken from the frame and fixed as follows :—

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A horizontal recess 3-in. x 6½-in. was carefully cut in the outside of one of the longitudinal walls and the channel iron introduced; the positions of the 10 holes for the binding bolts marked off, the channel was then removed and these holes carefully drilled right through the wall, the diameter being slightly larger than that of the bolts. Great care was taken to prevent shaking and cracking of the brickwork.

The channel was then filled with brickwork in cement, leaving the holes clear, and then placed in the recess, wedged and built in with cement brickwork.

This procedure was repeated inside, and the two channels were bolted together, forming a box girder, the faces of the girder being flush with the faces of the 10-in. brickwork.

This process was repeated in the other longitudinal wall and the two end walls and the whole frame bolted up and made secure. The whole was now imbedded in the building. The cross bracing channels were now fitted and bolted to the frame, and the five diagonal timber struts (Plate II, Fig. 1) were fitted and tightly wedged.

Fixing the Rail Joists.

Under each of the six pillars, holes 14-in. wide and 6-in. high, immediately below the channel frame, were cut, and the rail girders passed through (Plate IV, Fig 9), 16-ft. projecting beyond the west wall, and the west ends resting on the new foundations previously built; the ground had previously been floored with sleepers to give a solid foundation for the rails throughout both outside and inside the building, and when placed in position the rail girders were levelled and tightly wedged up. Timber sleepers had also been sunk into the brickwork of the new foundations (Plate V).

The level of the rail girders was very carefully maintained throughout.

The weight of the building was now carried on the rail girders under the channel frame and the foundations of that part of the brickwork which had not been cut away to allow for the fixing of the channel frame were now cut away with chisels; the whole weight was thus transferred to the six rail girders under the pillars.

Note.—At the time of cutting the 6 holes for the rail girders temporary brick piers were built under the projecting ends of the 40 ft. channels, these were now dismantled so that the whole of the building was separated from the foundations.

The co-efficient of friction was taken for steel on steel as 0.2, which, taking the weight as 150 tons, gave the friction to be overcome as 30 tons; this was probably high, as the rails were greased.

Six screw jacks of 10 tons lifting capacity were used, and were placed horizontally, so as to give a true horizontal pressure against

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the channel frame, each jack being placed centrally opposite each pier, and directly opposite the cross braces provided inside.

The bases of the jacks to start with butted true against the 14-in. x 14-in. pine baulks, which in their turn bore against six rails, 9-ft. long, sunk 6-ft. into the ground (Plate IV, Fig. 10 and Plate V), which were themselves strutted against the foundations of the Outward Parcel Office. The jacks were fixed slightly above the centre of the channel iron frame. Sal wood pieces, 3-ft. long, bearing flush against the face of the channel and the vertical face of the brickwork piers to produce a cushion and extend the area of pressure.

Every endeavour was made to work the jacks exactly the same amount in each stroke and all together. The handles of the jacks at the beginning of each stroke were placed at the same angle, and were worked to the word of command. The rails were kept well greased throughout the operation.

After four strokes of the jacks the building began to slide.

The extension of the jacks was 15-in., so that when the building had moved forward by this amount the jacks had to be screwed down again and packings introduced behind the bases, when the operation was repeated. The packings used in this work were firewood sleepers.

BEDDING BUILDING ON THE NEW FOUNDATIONS.

The 10 gaps, each 6-ft. long, between the double rail joists, were packed up with cement concrete (special frames having been made out of old Deodar planks) rammed home with wooden rammers from both sides so that it flowed right through under the channels and filled up all crevices between the bottom flanges of the two channels forming the box girders.

The concrete having been allowed to set, the packings under the rail joists were removed and the rail joists pulled out, one by one, the holes of the first joist having been filled in before the second was touched.

The under pinning frame was then dismantled, and was the reversed procedure of putting it in. One channel was taken out at a time, and all masonry made good with cement brickwork. Cement slurry being forced in under the old walls before refilling the channel gaps.

The whole of the iron work used in the operation was recovered. Levels were carefully taken and no settlement whatever occurred after the building was seated on its new foundations.

The replacing of the fittings inside the latrine was taken in hand, the original E.W. channel was re-used with the exception of 6-ft., which was broken in the course of dismantling.

The latrine was put out of use on March 30th.

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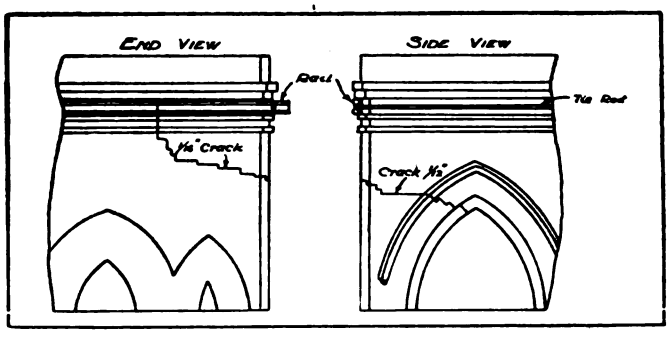
Building was shifted on April 12th and 13th.

Latrine was restored to use, absolutely completed in its new position May 11th.

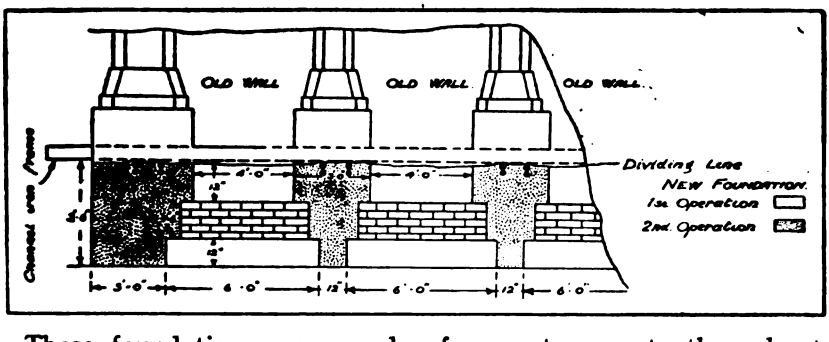
NOTE.

The building was moved successfully for 11-ft. 4½-in. without any sign of cracking or other injury, but after this at 11-ft. 9-in. a slight crack was noticed about 5-in. from the apex of the S.E. Gothic arch and tell-tales were fixed; on further movement this crack extended, and when it had moved a total distance of 12-ft. 4-in.,



by which time the eastern wall was centrally over the old foundation of the west wall, the crack had opened to ⅛-in. and showed signs of further extension. It was, therefore, decided to stop further operations, as sufficient room had been made for a 16-ft. road between the building and the Outward Parcel Office, and to excavate and build new foundations under the west wall and bed the east wall on the old foundations. It was not worth while risking serious damage to the building, which might necessitate the rebuilding of a considerable portion of the latrine.

The foundations were constructed sectionally between the rail girders, stepping them, so that when the portions under these were taken in hand they would bond and key.



These foundations were made of cement concrete throughout, rather an unnecessary expense, but the object was to get the work finished quickly, and we did not want to have to wait for lime

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concrete to set. When the building was actually bedded on the foundations there was no settlement at all.

The cause of the cracking is one which calls for remarks, and it would be interesting to have the ideas of other people on it.

The writer is of opinion that the crack was due to uneven and irregular pressure being transmitted to the building by the jacks, although every possible precaution was taken to work the jacks absolutely synchronously, the human element entered, and it was found that some jacks had completed their stroke while the strokes of others were still in progress. Another contributory cause in the opinion of the writer is the packing at the back of the jacks when they were moved forward. The packing used consisted of firewood sleepers; these were worn and had by no means an even bearing surface, the packing was wedged with wooden wedges at intervals, but the writer is inclined to believe that bending occurred in these sleepers, and as they were not continuous, this was a contributory to uneven pressure against the building.

A curious fact is that in the two cracks in the roof, which were found before the building was moved, no movement whatsoever took place.

It should be mentioned that the arch openings above the 10-in. walls were not bricked up, vertical struts only, tightly wedged, were introduced from the apex of the soffit to the top of the 10-in. wall; it is doubtful, however, whether the bricking up of these arches would have prevented the cracking, as immediately the crack was observed these arches were bricked in, but it did not prevent the crack extending.

A point which leads the writer to believe that the cracking was due to uneven pressure is that the west wall, *i.e.*, that furthest from the jacks, was undamaged in any way; the pressure was equally distributed to this wall by the cross bracing channels of the frame and the diagonal timber struts.

TOTAL EXPENSES INCURRED IN SHIFTING THE LATRINE BODILY, INCLUDING ALL CHARGES WHATSOEVER UP TO 15TH MAY, 1924.

	Rs.	A.	P.
Labour (as per detail below)	1,274	0	0
Material (Do.)	1,256	0	0
TOTAL	2,530	0	0
Total amount sanctioned in Resolution 1066 of 1923-24	5,000	0	0
Net saving..	2,470	0	0

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Detail of Labour.

	Rs.	A.	P.
(1) Workshop charges for month ending 15th March, 1924	125	0	0
(2) Inspector of Works, Special Works, labour pay sheet charges for month ending 15th April, 1924	279	0	0
(3) Workshop charges for month ending 15th May,1924	70	0	0
(4) Inspector of Works, Special Works, labour pay sheet charges for month ending 15th May, 1924	400	0	0
(5) Contractor's Bill	400	0	0
	1,274	0	0

DETAIL OF MATERIAL.

Debit	Rs.	A.	P.	Credit.	Rs.	A.	P.
(1) Old sleepers 197 @ Re. 1	197	0	0	Old sleepers 132 @ Re 1 each	132	0	0
(2) Channel Iron 6″ x 3″ 256-ft. @ Rs. 12 per Cwt.	397	7	0	Channel Iron 6″ x 3″ 256-ft. @ Rs. 6 per Cwt.	198	11	6
(3) Angle Iron 3″ x 3″ x ⅜″ 8-ft. @ Rs. 14 per Cwt.	7	3	0				
(4) W.I. Rivets 2″ x ⅝″ 6 lbs. ... @ Rs. 35 per Cwt.							
(5) W.I. Bolts 1½″ x ⅝″ 13 lbs. @ Rs. 35 per Cwt.	11	4	0				
(6) W.I. Nuts ⅛″ 17 lbs. ... @ Rs. 35 per Cwt.							
(7) Iron round ¾″ 123-ft. @ Rs. 16 per Cwt.... ...	35	14	6	Bolts 1′—4″ x ⅞″ 30 Nos....	15	0	0
(8) W.I. Bolts 11″ x 1″ 1 Cwt. 2 qr. and 20 lbs. @ Rs. 28 per Cwt.	47	0	0	W.I. Bolts 11″ x 1″ 1 Cwt. 2 qr. and 20 lbs. @ Rs. 28 per Cwt.	47	0	0
(9) Iron round 1¼″ 110-ft. @ Rs. 16 per Cwt. ...	65	9	0	Iron round 1¼″ 100-ft. @ Rs. 16	59	9	6
(10) Rails D.H. 183-ft. ... @ Rs. 0.62 per Lft.				Rail D.H. 183-ft. ... @ Rs. 0.62 per Lft.			
(11) Rails Bull headed 348-ft. @ Rs. 0.62 per Lft.	329	3	6	Rail Bull head 348-Lft. ... @ Rs. 0.62 per Lft.	329	3	6
(12) Iron sheet ⅛″ 6 Sft. @ Rs. 16 per Cwt. ...	13	1	9				
(13) Iron round 1½″ 13-ft. @ Rs. 16 per Cwt.... ...	6	4	6	Iron round 1½″ 13-ft. ...	6	4	6
(14) Nuts 1½″ 2½ lb. @ Rs. 28 per Cwt.	0	10	0				
(15) W.I. bolts 8″ x ¾″ 17 lb. @ Rs. 28 per Cwt. ...	4	4	0				
(16) Nails 6″ 2½ lb. @ Rs. 35 per Cwt.	0	12	6				
(17) Paint chocolate 4 galls. @ Re. 1 per gall. ...	4	0	0				
(18) Spun yard 6 lbs. ...	2	8	0				
(19) G. I. Bolts 1″ 3 gross and 4 dozens @ Re. 1 per gross	3	5	3				
Carried over ...	1,125	7	0	Carried over ...	787	13	0

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DETAIL OF MATERIAL—(*cont.*)

DEBIT.	Rs.	A.	P.	CREDIT.	Rs.	A.	P.
Brought forward ...	1,125	7	0	Brought forward ...	787	13	0
(20) Nuts ⅜" ¾ lb. @ Rs. 28 per Cwt.	0	3	0				
(21) Iron round ⅜" 10-ft. @ Rs. 16 per Cwt. ...	0	8	6				
(22) Steelhex ¾" 1-0 ft. ... (23) Steel round 1¼" 21-ft. ... } As. 8 per ft.	15	8	0				
(24) Rail metre gauge 6-ft. @ As. 6 per ft.	2	4	0				
(25) Angle Iron 4" x 4" x ⅜" 5-ft. @ Rs. 14 per Cwt.	6	1	9				
(26) Bolts 1½" x ⅝" 16 lbs. @ Rs. 28	4	0	0	Bolt 1½" x ⅝" 16 lb. @ Rs. 28...	4	0	0
(27) Cement 173 Mds. @ Rs. 3 per Md.	519	0	0				
(28) Leather 2½ lbs. @ Re. 1 per lb.	2	8	0				
(29) Socket G.I. ¾" 10 Nos. ... (30) Elbow G.I. ¾" 1 No. ... (31) Tee G.I. ¾" 1 No. ... (32) Bend G.I. ¾" 1 No. ... ... } As. 8 each	6	8	0				
(33) Nuts ⅝" 4 lb. @ Rs. 28 C.	1	0	0				
(34) E.W. pipes 4" dia. 2 No. @ Re. 1 each	2	0	0				
(35) Stone chips 250 Cft. @ Rs. 34% Cft.	85	0	0				
(36) Sutna lime 149 Cft. @ Rs. 35% Cft.	52	2	6				
(37) Ashes 275 Cft. @ Rs. 6/4% Cft.	17	3	0				
(38) 1st Class bricks 9,300 @ Rs. 18 per %.	167	6	6				
(39) Brick ballast 456-Cft. @ Rs. 9% Cft.	41	0	9				
	2,047	13	0		791	13	0
				Net amount debitable	1,256	0	0

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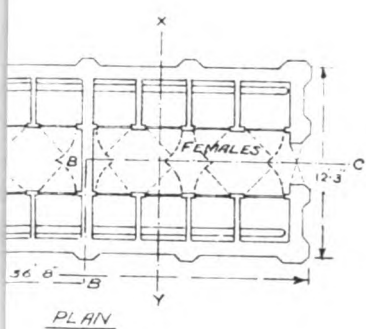
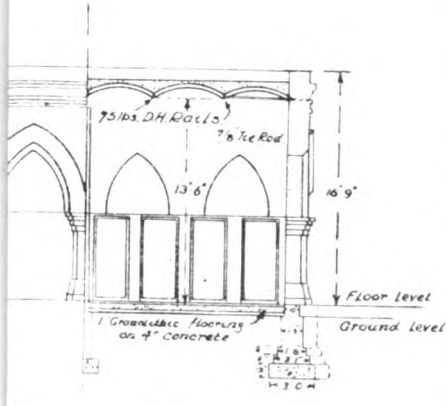
BUILDING AT DELHI.

Plate I



PLAN



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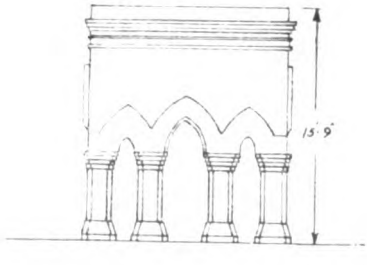

END VIEW

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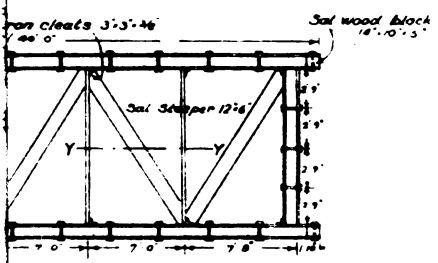
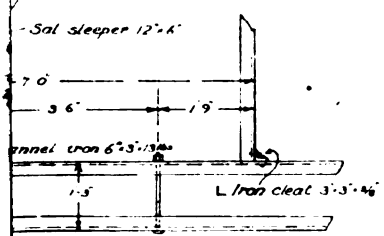
BUILDING AT DELHI.

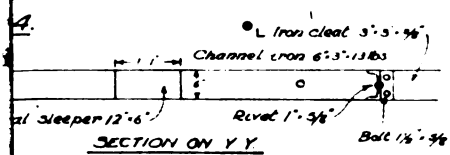
Plate. 2



PLAN



RAILS AT A.B



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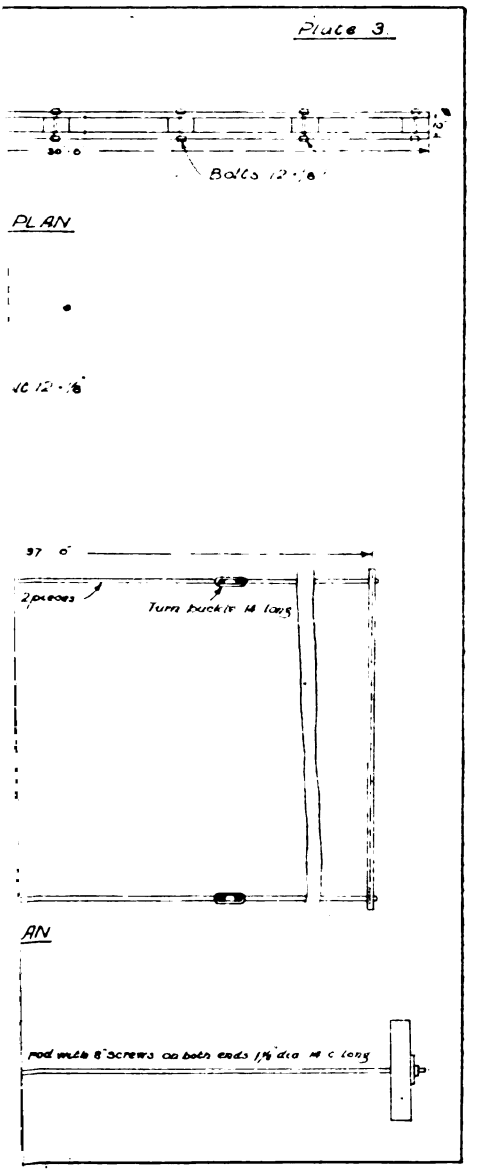
BUILDING AT DELHI.

Plate 3



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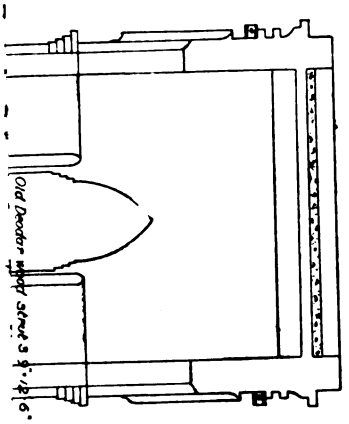
ILDING AT DELHI.

Plate. 5.



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THE PRINCIPLES OF DEFENSIVE WARFARE.

By COLONEL J. F. C. FULLER, D.S.O.

INTRODUCTION.

BEFORE the outbreak of the last Great War, all armies were organised for mobile warfare, and many soldiers considered that the war would be rapid and short. To-day, for similar reasons, all armies are organising for a war of movement, and the greatest surprise of the last war, namely, its static nature, is not only being forgotten, but to mention its reoccurrence is to risk being classed as a heretic. In 1914, as M. Bloch had foreseen twenty years earlier, it was fire power and human nature which were the parents of the trench. Since 1914, human nature has not changed, but whilst, then, an infantry division possessed 24 automatic weapons, to-day it possesses over 500. In 1914, the maximum (aimed) fire-power of a division, in S.A.A., was about 55,000 rounds a minute, to-day it is 155,000. Thus far the conclusion is that, if a great war broke out to-morrow, unless armies possess large numbers of tanks, it would be a war of trenches, for, if they do not, it will take at least a year to produce them in any quantity.

1. THE FOUNDATIONS OF THE DEFENSIVE.

The following theory is based on the experiences of history, therefore to discard it is an act both dangerous and foolish :—

(i) The offensive should be assumed on all occasions when circumstances permit of it.

(ii) Offensive action should spring from a strong defensive base.

(iii) The defensive should be so organised as to permit of it changing into an offensive at the shortest possible notice.

(iv) The offensive cannot be too strong, therefore the defensive should not employ a weapon beyond the minimum necessary to establish security.

The following drawn from the past are errors worth remembering :

(i) The offensive languishes on that side which is least prepared to wage war, and which is, through ignorance of the principles of war, blinded by the belief that the enemy must be held back at all points and that, consequently, it is necessary to be everywhere equally strong in men, and superlatively strong in defences.

(ii) The neglect of peace teaching, based on the experience of former wars, generally leads to the creation of

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" impregnable positions," in place of such preparations as will aid a rapid assumption of the offensive.

(iii) The all but total depletion of a reserve, that is, a striking force, on account of the stringing out of troops for purely defensive tactics, such as the passive holding of trenches, villages and fortified positions, renders a sustained offensive impossible.

(iv) The general demoralization and disorganisation of all ranks by the incessant creation of new defences, and the repair of old ones, detrimentally affects training and leadership, and, consequently, lowers the offensive spirit of all concerned.

I will now briefly consider the principles of war in their defensive aspect. Bearing in mind that there is no hard and fast dividing line between the offensive and defensive in warfare, we find that the object is the same. Shielding does not consist solely in preserving our own existence, but in preserving it in order that we may the more economically destroy the enemy, consequently, a defensive battle should be based on an offensive plan, which through force of circumstances cannot at once be put into operation.

Superiority of weapons at the decisive point means superiority of offensive power, and the lack of this superiority is frequently the direct cause of defensive action. If men are squandered in the attempt to avoid blows they will never be in a position to give them, and not giving them, they allow their enemy to reduce his defensive strength to a minimum and to increase his striking force in proportion. It was against this type of warfare that Napoleon inveighed when he wrote to his brother, the King of Spain, saying : " The cordon system is only good against smugglers," yet, for over three years, the grand tactics of the Great War on the Western Front were based on this system.

Infringing the principle of concentration, the cordon system simultaneously infringes the principle of economy of force. The defensive becoming the main object, a time arrives when the offensive becomes inoperative, not through lack of weapons, but through the impossibility of massing them. Garrisons must be in proportion to the trenches they occupy, and if trenches are over large, garrisons cannot be relieved without seriously weakening them. Ten men will hold a blockhouse, and a blockhouse may delay a brigade, ten men will not hold a fortress ; therefore, in our defensive plans, do not let us build fortresses when blockhouses will suffice. The strength of defences does not rest in their size, but in the harmony between their size and the strength of their garrisons.

Besides the danger of weakening established defences in order to build up a strong reserve, another danger presents itself, namely,

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the danger of excessive immobility due to over extension, which leads to an infringement of the principle of mobility.

Consequently, before we plan our defences, we should carefully consider the following maxims :—

(i) When from a state of defence the offensive is assumed, this act should in no way disorganise the existing defensive arrangements.

(ii) Any delay in the assumption of the offensive from the defensive may prove fatal to both operations.

(iii) In offensive action, moral weakens in proportion as improvisation increases.

The first is a violation of the principle of security, the second of mobility, and the third of co-operation.

The principle of surprise finds an all but unlimited application in the defensive. I will take one small instance as an example—the siting of wire entanglements. During the Great War, the tactical effect of wire was immense, but the use made of it during the first two years of the war was beneath contempt. The true use of wire does not lie in fencing off areas of ground as British, French or German, which, during the Great War, was so frequently the case ; but of so increasing the offensive power of weapons that their numbers can be reduced in defensive positions. For instance, in trench warfare great risk was experienced in placing a little wire in front of the front line fire trenches, which, more frequently than not, constitute a target for the enemy's guns. Instead, entanglements should be constructed behind those trenches where acres can be set up in a single night. In front of the fire trenches, ground, for this purpose, is normally limited, in rear of them, unlimited, and, being so obviously the place for wire, is frequently overlooked. This error is mainly due to the spell of the cordon system, which aims at holding ground, as if ground were the object of battle ; it is not, for the object is the destruction of the enemy's strength.

To avoid the excessive use of men for purely defensive work, we have recourse to a very simple arrangement known as outposts. These perform two duties : the first, watching for the enemy ; the second, delaying his advance so that the troops in rear may assume the offensive before the enemy can surprise them.

If in field warfare it has been found that seldom more than one-eighth of a force is required for protective duties, a greater number should be unnecessary in trench warfare, where defences and obstacles abound. True, in trench warfare, the opposing forces may often be as many yards apart as in field warfare they are miles ; but military spaces are not measured with a foot rule, but by the obstacles they contain and the time taken in crossing them.

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In order to obviate the inherent disadvantages and vices of the cordon system of defence: firstly, the line of resistance must be chosen from the point of view of the grand offensive; and, secondly, from that of the decisive counter attack. The line of resistance should be a fortified line, and the ground behind it should be prepared:

(i) To aid the offensive forward of the line.

(ii) To assist the defence of the line itself.

In front of this line of resistance should be constructed a line of observation, consisting of a continuous trench line or a line of posts. Between this line of observation and the line of resistance should be constructed a line of strong works, the tactical object of which is:

(i) To protect the observation posts if they are attacked.

(ii) To break up, like groins, an enemy's attack should it sweep through the observation posts, so that a counter-attack, from the line of resistance, may find before it a morcelated and demoralised force.

The ground between the observation line and the line of resistance should be prepared:

(i) To facilitate our own offensive.

(ii) To hinder the enemy's offensive.

Masses of trenches should be avoided, they deplete military endurance and also the national exchequer.

We now come to our last principle, the principle of co-operation. Before the outbreak of the Great War, the doctrine of the offensive, due to lack of logical thinking, grew top heavy—through the defensive being ignored; the result of this, during the war, was a chaos of defensive actions.

One system, even if an unsound one, is safer than a score of brilliant ones simultaneously attempted, because the former means unity of action, whilst the latter spells dispersion of force. We cannot afford to regulate our defences on guerilla lines. Given a doctrine, given a definite system of defence, based on the proved principles of war, this system should be applied to the whole of a defensive line, whether the length of this line be five hundred yards or five hundred miles. This is sound generalship. Whatever the length of the line may be, it should be viewed as a unit, that is, as one zone of possible attack. It should be viewed from an offensive as well as a defensive standpoint, and the frontage of ultimate attack should be selected in accordance with the objective. Its holding and decisive attacking forces being distributed according to the principles of concentration and economy of force. Once viewed as a unit, it should be divided into sections, the extent

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of each section being arrived at after a careful tactical study of the ground. Further, each section should, when possible, bear a direct relationship to the larger tactical units—divisions, corps and armies, and all sections should be placed under the command of their own generals and their respective staffs; and, as long as the line is held, these should be its permanent officials. The garrisons may come and go, but the staffs should remain; they form the skeleton of the whole defensive system, the garrisons being the changing tissues.

In trench or siege warfare, until each section is organised under its own fortress commander and ceases to be a mere tactical "doss-house," the offensive will languish, for it cannot be carried out effectively on the maxims of partisan warfare—each unit carrying out separate operations on its own, or hesitating to do so for want of faith in the commanders on its flanks.

To sum up:—

(i) The objective must be decided upon.

(ii) The plan of defence for the whole front must be worked out.

(iii) The entire defences of the whole front must be placed under one commander.

(iv) The front must be divided into sections.

(v) The sections must be divided into sub-sections.

(vi) The sections and sub-sections must have their own commanders.

(vii) The requisite garrisons must be placed under the orders of these officers.

(viii) The remaining troops must be kept in reserve under their own commanders and trained for offensive warfare.

In one word, "organise." The trenches must be looked upon as defended barracks, to and from which units may come and go without altering rules, structure and accommodation; and not as mere camping grounds where each unit selects its own pitch. This will lead to co-operation in its highest sense, for not only will all know what they have to do, but all will know that, as they are part of *one* organisation, those on their flanks will equally know it, and that all will act together according to *one* plan (and not on a hundred and one), irrespective of reliefs, irrespective of changes.

2. The Tactics of Trench Warfare.

General Dragomirov once wrote, with reference to field defences: "Make the firing line at right angles to the direction you want to command, and see that the enemy is unable to enfilade this line. All fortification is contained in these two principles." Though

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this is correct, it is necessary somewhat to amplify this statement as follows :—

(i) Trench systems must be planned so as to enable the offensive to be assumed from them.

(ii) Troops must be so distributed as to gain complete liberty of manœuvre behind the front held; for an attack is generally more easily frustrated by attacking the enemy in some other quarter. To meet it directly is, frequently, to play into the enemy's hands.

(iii) Defensive lines must be planned with the idea of counter-attack, especially the rear lines, and the troops must be massed in accordance with this idea. This means that all reserves—men, munitions, guns, etc., are ready for immediate action, are mobile and that the men are in a high state of training.

(iv) Minor attacks must be made in order to create a favourable opportunity for decisive action. A definite policy must unite them, in order to improve the possibility of an eventual offensive.

(v) The defence must never be content with warding off the enemy's blows, for the object, the destruction of the enemy, forbids this.

(vi) Trench warfare must be looked upon as subsidiary to the ultimate destruction of the enemy's field armies. This being so, our trenches must be garrisoned so as to enable sufficient men to be trained in field warfare.

(vii) Trench warfare must be based on the maxim that "the offensive is the soul of the defence;" trenches, in themselves, being merely a temporary protection.

(viii) Defensive positions must be selected in view of economising personnel so that the power of the offensive may be increased. Consequently, before ordering new trenches to be dug, it should be remembered that every extra yard or two may mean one man less wherewith to strike a blow at the enemy.

(ix) Defensive frontages must be considered with reference to the offensive. Trenches having been garrisoned and their reliefs detailed, at least half the total force should remain in hand for decisive action.

(x) Trenches must be dug with the object of reducing the number of men required for the defensive in order to add to the general reserve or striking force.

(xi) The trench garrisons, those troops represented by sentries, picquets, supports and reserves, should seldom, if ever, exceed one quarter of the total troops allotted to any one section.

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(xii) As trench warfare adds little to skill, better organisation, training and *moral*, every attempt should be made to reduce the number of men employed in it, so that more can be trained for offensive action.

To return once again to General Dragomirov's maxim, for centuries past, in fact, from the earliest days of warfare, both his requirements have been met by disposing the defenders in such a manner that they could take in flank an enemy's attack directed against their front or flanks.

There are two means of doing this :

(i) By the use of weapons.
(ii) By the use of barrier and deflecting obstacles.

To use weapons with the greatest effect, it is necessary to be shielded ; therefore, in former times, walls or ramparts were built, and in order to enfilade an attack these walls were provided with bastions. In other words, a series of towers, or strong points, were linked up by curtain walls, and between these bastions were constructed sally ports, from which the offensive could be assumed. The entire work was surrounded by a moat or ditch, which not only constituted an obstacle, but a trap, which once entered would be difficult to escape from, on account of enfilade fire sweeping down it from flanking works.

Throughout the history of war, whenever an improvement in artillery has rendered the cannon superior to the musket or rifle, fortresses and field defences have abounded ; and, if we want to study the principles of these defences in detail, we cannot do better than go back to the days of Vauban and substitute, in place of bastions, strong points ; in place of curtains, narrow trenches ; in place of moats swept by grape shot, wire and trenches swept by machine guns.

Analysed, all these systems may be reduced to three tactical requirements :—

(i) The maintenance of an unbroken front.
(ii) The enfilading of a hostile attack.
(iii) The rapid assumption of the offensive.

I will consider these in turn.

The Maintenance of an Unbroken Front is generally dependent on the denial of flanks to an enemy's attack. This may be accomplished by :—

(i) A continuous system of trenches.
(ii) Detached works linked together by vast quantities of wire entanglement.

If the enemy is to be attacked, the advantage of the first system needs no explanation, as a continuous system of trenches is a

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necessity as a jumping off line. If the enemy is simply to be withheld, the advantage of the second system is that it requires very few men for defensive work, consequently it permits of the majority being relegated to the offensive reserve. Its disadvantage is that vast fields of entanglement and the absence of lateral communications seriously impede our own advance and assault.

Considering these points, there can be little doubt that for those sections of the front which have been selected for offensive operations, the system of the continuous line is best; and, as men are never unlimited in number, it will, consequently, be necessary to adopt the system of detached works for those sections of the line which are purely defensive. Unless this rule be strictly observed, the principles of concentration and economy of force will be violated.

If this contention be correct, it also follows that, whenever the conditions render the offensive either impossible or ruinously costly, it is only right to adopt the second system in place of the first, for, by so doing, endurance will be economised. The most important condition which regulates this adoption in Western Europe is weather; consequently, during the winter months, the system of detached posts should, when possible, be adopted.

What did the Great War teach us of entrenchments from the constructive point of view? This: that, though it is possible to dig hundreds of miles of trenches in the summer, it is next to impossible to maintain hundreds of yards in the winter, unless these trenches be most solidly revetted and boarded and most carefully drained. When trench systems run into thousands of miles, seldom are material and labour sufficient to complete all the trenches dug during the summer or to maintain them during the winter. The result being that, though in places the system of the continuous line is most suitable during the summer time, it is not only most unsuitable during the winter, but a positive danger, for the more it is patched up the more it falls in. When once a trench is half full of water, unless this water can be removed by drainage, and it often cannot be, nothing destroys it more than trying to clear it out and revet it; every soldier knows this.

It would appear, therefore, that when once the offensive is brought to a standstill through the opposing forces going to earth, the defining of the zones of attack and defence should be a commander's first consideration; and that, until these have been defined, no elaborate system of trenches should be dug, so that every board, every hurdle, every gabion may be economised in the purely defensive zones in order that the trenches in the offensive ones may be able to withstand the rigour of the winter and be in a fit condition to aid an early spring advance. Further, the less work required during the winter, the more men will the units, destined for the offensive, be able to train. To trust on weapons

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as the best means of defending the offensive zones, and on obstacles for defending the defensive zones, because our own weapons are the best means of aiding our advance, whilst our obstacles often impede our movements as much as they impede the enemy's. During the winter time it is generally feasible, temporarily, to convert such portions of the offensive zone, as are rendered unattackable on account of weather, into defensive ones; and though this will mean that many of the trenches necessary to an offensive will fall in, these can be more thoroughly repaired during the first fortnight of fine weather than during months of rainy.

In truth, the entire problem of defence is one of the most rudimentary common-sense; it may be summed up as follows:—

(i) Trenches from which an offensive may be assumed must be defended by missiles, consequently a continuous line is necessary.

(ii) Trenches which are purely defensive must be defended by obstacles flanked by fire, consequently detached posts (well hidden machine gun blockhouses) are necessary.

(iii) During the summer an army should be prepared to assume or repulse an offensive.

(iv) During the winter an army should be prepared to assume a strong defensive, that is, one which will require as few weapons as possible so that a maximum number of men may be trained for offensive action the following summer.

The Enfilading of a Hostile Attack.—The power of enfilade fire cannot be exaggerated in trench warfare; in the offensive it constitutes the chief means of accelerating an attack, in the defensive of frustrating it. This is not usually observed on account of the obsession that parallel entrenchments are the surest means of defence. As the flank of an attack is the most vulnerable point, our tactics should aim at forcing an enemy, should he attack us, to offer us a flank in such positions as will cause him the greatest inconvenience and loss. If nature does not furnish us with these positions, then, by the aid of obstacles, must we create them; we must so place our entanglements that they will not only come as a surprise to the enemy, but will force him to halt in such positions as will render his flank, or flanks, an easy target to our fire.

Take, for instance, the wire entanglement in front of a fire trench. If, instead of constructing it parallel to the trench it protects, it is constructed in a zig-zagged manner, it will not only form a more difficult target to the enemy's artillery fire, but it will enable an enfilade and cross fire to be directed along its salients. Again, if behind this entanglement we dig an observation trench, this again should consist of a series of salients, or untraversed zig-zags, in principle much like the old pentagonal fortresses of two hundred

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years ago. Such a trench will not only flank the wire, but will, in itself, constitute an obstacle, for internally it can be flanked by rifle or machine gun fire. Every trench dug should help the offensive. If lost, its existence should at once add to the strength of the defensive; this is the whole art of entrenchments.

If between the line of observation and that of resistance, an intermediate line of works is constructed, these works should be so sited as to cause the enemy, should he attack them, to form perpendicularly or obliquely to the line of resistance and so offer either one or both flanks open to counter-attack.

Siting of wire and siting of fire trenches is simply a matter of common-sense, based on the simplest of simple maxims, namely: "All obstacles and trenches should be so sited as to cause the enemy to offer a flank to our fire without compromising the advance of our counter attack."

The Rapid Assumption of the Offensive.—The possibility of rapidly assuming the offensive depends on distribution, ground and observation. If the front line be made the line of resistance, the offensive may be rapidly assumed from this line if our observation be good and the enemy's bad; but, if reverse conditions prevail, it is probable that the garrison will be pounded to death before an offensive can be launched. If a rear line, not observable by the enemy be chosen, then the ground between it and the front line must be sufficiently clear of obstacles to permit of a rapid advance. The chief reason why a rear position should be chosen for resistance is that whilst the adoption of the front line for the offensive is immediately restricted by the proximity of the enemy's trenches, a rear line is not so affected, and the further back this rear line is dug the more room have we wherein to manœuvre our entanglements.

This manœuvring of entanglements, with a view to the disorganising of an enemy's attack and the facilitating of our own counter-attack and offensive, is a point which has not met with sufficient recognition in the past.

3. Siting and Garrisoning Trenches.

As a trench is virtually a shield, it should be dug where it will provide the greatest protection against whatever weapon can do its occupants the greatest harm, and also assist in the development of the power of such weapons as will prove most effective against the enemy. In a war of trenches, excluding mechanically propelled weapons, such as tanks, it is the gun and howitzer which to-day rule the field, consequently our best plan is:—

(i) Offensively, to select for our artillery the very best observation stations possible, positions from which those of the enemy can be commanded.

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(ii) Defensively, to site our infantry trenches in such places in which they cannot be directly observed from the enemy's artillery observation posts.

If we do this we shall be carrying out the principles of the offensive and security, namely :—

(i) The destruction of the enemy, or the maintenance of a position from which the maximum artillery effect can be obtained.

(ii) The protection of ourselves, or the maintenance of a position against which the minimum artillery effect will be felt.

Subsidiary to these are the following :—

(i) The selection of a position which will enable our guns eventually to advance rapidly and safely.

(ii) The selection of a position which will not permit of the enemy's guns doing likewise.

Combined, we obtain the following theory :—

That a position to be considered sound must be one which cannot be enfiladed, but which will facilitate our artillery enfilading the enemy, whether stationary or advancing; further, that it will facilitate our advance by securing our batteries from enfilade fire as they move forward.

A position should first of all be looked at from our possible observation posts, next from those possible to the enemy, and only then should trenches be sited. This system is always practicable in the case of our rear lines of defence. The front line, the siting of which is so often governed by the enemy's position and opposition,* should, as far as possible, be treated in the same way. A position should always be considered from the point of view of enfilade fire, particularly that of artillery and machine guns. Purely parallel systems of defence should seldom be allowed. When such are inevitable, they should be connected up by a system of fire—communication—trenches which will divide the spaces between them into a series of fortified triangles and quadrilaterals. A system of trenches should always be sited so that at least a part of it commands a direct view of the enemy's position, whilst the remainder affords direct protection against his fire.

Having sited our trenches the next question is how to garrison them.

The correct manner of garrisoning a line of trenches depends entirely on the purpose for which the trenches are built, whether for an offensive or defensive operation. If offensive, the strength of the garrison may roughly be arrived at by weighing the con-

(*) In the Great War, most front lines had little relationship to security, as they were generally entrenched field battle fronts.

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ditions of numbers, ground and armament, that is, by calculating how far these favour the enemy or ourselves. If defensive, then the number of detached posts requisite to enfilade the wire fields. Thus, by an application of principles to conditions, may economy be effected and guessing reduced to a minimum.

The front line should be looked upon as an outpost line :—

(i) When a strong line of resistance runs behind it.
(ii) When the front to be held is purely a defensive one.

The front should be looked upon as a battle front when it constitutes the line of resistance itself. Resistance, here, being interpreted in a twofold sense :—

(i) Resistance due to the formation of the ground.
(ii) Resistance due to the intention of holding the front line offensively.

In trench warfare, as in field, the whole question of holding the line dwindles down to the simple formations of outposts and battle outposts. In field warfare the former are used when the opposing forces are so placed that they are unable to attack one another without giving some warning of their approach ; the latter, when a surprise attack is possible, that is, when the enemy, in force, is close to us and few obstacles lie between us and him, and, further, when the ground which we occupy is of great tactical value.

By combining these two systems we get a third, which admits of both being adopted according to circumstances. This system demands the most careful co-ordination, for being based on a dual conception of defence, it is liable to lead to doubt and disorder. To control it, we must fall back on our principles and consult these : determine our zones of offensive and defensive action, consider conditions and then plan accordingly, making absolutely certain that every commander knows what he has to do, and only allowing those commanders to adopt the outpost system in which a retirement of the garrison will not uncover the flanks of the sections on its right or left, or will create for the enemy's attackers a cul-de-sac completely raked by enfilade fire.

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BATTLE HONOURS OF ROYAL ENGINEER UNITS.

The Army Council has recently issued the "Complete List of Battle Honours Awarded," to the regiments of Cavalry and Infantry "for the Great War." The location of every battalion was determined after a great deal of research and the Battle Honours were awarded in accordance with the terms laid down by a "Battles Nomenclature Committee," appointed in August, 1919. This Committee tabulated Actions, with a definite system of nomenclature denoting their relative importance, and defined the geographical and chronological limits of each action. The Report of the Committee is an official publication, and can be obtained through a newsagent for two shillings.

Although the granting of Battle Honours to Royal Engineer Units is unfeasible—since the motto "Ubique" covers the whole field of operations—it is considered that it would be of very great interest to the Corps if complete lists were compiled to show what Battle Honours would have been gained by the various units which participated.

Lieut. James has already given, in the *Journal of the Royal United Service Institution*, most interesting lists of the higher formations which were present at each battle. The lists published below have been prepared by Colonel G. R. Pridham, D.S.O., O.B.E., and show the units of Royal Engineers which were actually engaged in each Battle. It is recognised that there may be possible mistakes and omissions from the lists, especially in the case of smaller units, as these have not so far been traced, and their omission from the lists does not necessarily mean that they are not entitled to the Honours. It is further regretted that the present lists do not extend beyond September, 1916, and that of the many "side shows" only the Gallipoli Campaign is at present included.

It must be clearly understood that the lists are in no sense authoritative.

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RETREAT FROM MONS, 23rd AUG.—5th SEPT., 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st. Fd. Sqdn.	1st. Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
23rd. Fd. Co.	1st. Div.	,,	
26th Fd. Co.	,,	,,	
1st Sig. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
2nd Sig. Co.	,,	,,	
56th Fd. Co.	3rd. Div.	,,	
57th Fd. Co.	,,	,,	
3rd. Sig. Co.	,,	,,	
17th Fd. Co.	5th Div.	,,	
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	
7th Fd. Co.	4th Div.	,,	
9th Fd. Co.	,,	,,	
4th Sig. Co.	,,	,,	
1st A.C. Sig. Co.	1st A.C.	,,	
2nd A.C. Sig. Co.	2nd A.C.	,,	

Verifications.

6th Div. units not arrived.
No Works Co.
No Bridging trains.
No Ry. Units.
No Fortress Co.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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BATTLE OF MONS, 23rd-24th AUGUST, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
23rd Fd. Co.	1st Div.	,,	
26th Fd. Co.	,,	,,	Working with 3rd. Bde.
1st Sig. Co.	,,	,,	Communication to all Brigades.
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
2nd Sig. Co.	,,	,,	
56th Fd. Co.	3rd Div.	,,	
57th Fd. Co.	,,	,,	
3rd Sig. Co.	,,	,,	
17th Fd. Co.	5th Div.	,,	U.W.D. Missing.
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	

Verified that remaining units shown in B.E.F. Order of battle (Appendix to Official History of the War) were elsewhere.

BATTLE OF LE CATEAU, 26th AUGUST, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	1st Cav. Div.	,,	
56th Fd. Co.	3rd Div.	,,	
57th Fd. Co.	,,	,,	
3rd. Sig. Co.	,,	,,	Communication to Bdes.
17th Fd. Co.	5th Div.	,,	U.W.D's missing. verified from U.W.D. of 5th Sig. Co.
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	
2nd A.C. Sig. Co.	2nd A.C.	,,	

Verified that remaining units shown in B.E.F. Order of battle, (Appendix to Official History) were elsewhere.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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THE MARNE, 7th—10th SEPTEMBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
23rd Fd. Co.	1st Div.	,,	
26th Fd. Co.	,,	,,	
1st Sig. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
2nd Sig. Co.	,,	,,	
56th Fd. Co.	3rd Div.	,,	
57th Fd. Co.	,,	,,	
3rd Sig. Co.	,,	,,	
7th Fd. Co.	4th Div.	,,	
9th Fd. Co.	,,	,,	
4th Sig. Co.	,,	,,	
17th Fd. Co.	5th Div.	,,	
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	
1st A.C. Sig. Co.	1st A.C.	,,	
2nd A.C. Sig. Co.	2nd A.C.	,,	
3rd A.C. Sig. Co.	3rd A.C.	,,	

Verified that remaining units shown in B.E.F. Order of battle (Appendix to Official History of the War), were elsewhere.

THE AISNE, 12th—15th SEPT., 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
23rd Fd. Co.	1st Div.	,,	
26th Fd. Co.	,,	,,	
1st Sig. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
2nd Sig. Co.	,,	,,	
56th Fd. Co.	3rd Div.	,,	
57th Fd. Co.	,,	,,	
3rd Sig. Co.	,,	,,	
7th Fd. Co.	4th Div.	,,	
9th Fd. Co.	,,	,,	

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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THE AISNE—*continued.*

Unit.	Formation.	*D. *N.E. *E.	Remarks.
4th Sig. Co.	4th Div.	,,	
17th Fd. Co.	5th Div.	,,	
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	
1st Bridging Train	Army Troops	,,	Sent pontoons forward to Fd. Co.
2nd Bridging Train	,,	,,	,, ,, ,,
1st A.C. Sig. Co.	1st A.C.	,,	

42nd Co. L. of C. were in Braine 15.9.14, but took no part in battle technically or otherwise.

Verifications.

No Work Coys.
No Railway Units.
No Fortress Co.
3rd and 2nd A.C. Sig. Co., not in area.

LA BASSEE, 10th OCTOBER—2nd NOVEMBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
56th Fd. Co.	3rd Div.	E.	
57th Fd. Co.	,,	,,	
3rd Sig. Co.	,,	,,	
17th Fd. Co.	5th Div.	,,	
59th Fd. Co.	,,	,,	
5th Sig. Co.	,,	,,	
3rd Co. 1st S.& M.	Meerut Div.	,,	
4th ,, ,, ,,	,,	,,	
Meerut Divl. Sig. Co.	,,	,,	Hd. Qrs. of unit outside area, but unit worked within area.
20th Co. 3rd S. & M.	Lahore Divn.	,,	
21st Co. ,, ,,	,,	,,	
Lahore Divl. Sig. Co.	,,	,,	Hd. Qrs. of unit outside area, but unit worked within area.
2nd A.C. Sig. Co.	2nd A.C.	,,	Communication to Divisions in area.

Diaries of remaining R.E. Units in the Field inspected and units found to be elsewhere. 1st A.C. Sig. Co. not in area.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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MESSINES, 10th OCTOBER TO 2nd NOVEMBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	
1st Cav. Div. Sig. Sqdn.	,,	,,	Change of designation, the unit being formed in Oct.
2nd Fd. Sqdn.	2nd Cav. Div.	,,	
3rd Cav. Div. Sig. Sqdn.	3rd Cav. Div.	,,	
2nd Cav. Div. Sig. Sqdn.	2nd Cav. Div.	D.	No diary, presumptive evidence.

Verifications.

No other R.E. Units present under headings Works Cos., Bridging trains, Railway units, Fortress Cos.
3rd Fd. Sqdn. not present.
2nd Cav. Div. Sig. Sqdn. Diary commences 8/15.

ARMENTIERES, 13th OCTOBER to 2nd NOVEMBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	Had men wounded.
7th Fd. Co.	4th Div.	,,	
9th Fd. Co.	,,	,,	
4th Sig. Co.	,,	,,	
12th Fd. Co.	6th Div.	,,	
38th Fd. Co.	,,	,,	
6th Sig. Co.	,,	,,	
20th Fortress Co.	L. of C.	,,	

Verifications.

No other Fd. or Sig. Co. of 1st to 6th Div.
No Bridging trains.
No other Works Co.
No other Fortress Co.
No other Cavalry Div. units.
No A.C. Sig. Cos.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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YPRES, 1914, 19th OCTOBER—22nd NOVEMBER.

Units.	Formation.	*E. *N.E. *D.	Remarks.
1st Fd. Sqdn.	1st Cav. Div.	E.	
1st Cav. Div. Sig. Sqdn.	,,	,,	
3rd Fd. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	
23rd Fd. Co.	1st Div.	,,	
26th Fd. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
56th Fd. Co.	3rd Div.	,,	
17th Fd. Co.	5th Div.	,,	Detached from its own Division.
59th Fd. Co.	,,	,,	Detached from its own Division.
54th Fd. Co.	7th Div.	,,	
55th Fd. Co.	,,	,,	
1st Div. Sig. co.	1st Div.	,,	
2nd Div. Sig. Co.	2nd Div.	,,	
3rd Div. Sig. Co.	3rd Div.	,,	
7th Div. Sig. Co.	7th Div.	,,	
1st A.C. Sig. Co.	1st A.C.	,,	

Verifications.

57th Co. 3rd Div. not present.
7th & 9th Cos. 4th Div. not present.
12th & 38th Cos. 6th Div. not present.
4th, 5th & 6th Sig. Cos. not present.
29th, 20th & 42nd Cos. not present.
1st and 2nd Bridging Trains not present.
Railway Cos. not present.
2nd Fd. Sqdn. not present.
Indian Units not present.
2nd and 3rd A.C. Sig. Cos. not present.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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LANGEMARCK, 1914, 21st—24th OCTOBER.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
23rd Fd. Co.	1st Div.	E.	
26th Fd. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
54th Fd. Co.	7th Div.	,,	
55th Fd. Co.	,,	,,	
1st Divl. Sig. Co.	1st Div.	,,	
2nd Divl. Sig. Co.	2nd Div.	,,	
7th Divl. Sig. Co.	7th Div.	,,	
3rd Fd. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	
1st A.C. Sig. Co.	1st A.C.	,,	

Verifications.

56th & 57th Co. 3rd Div. not present.
7th & 9th Cos. 4th Div. not present.
12th & 38th Cos. 6th Div. not present.
1st Fd. Sqdn. 2nd Fd. Sqdn. not present.
1st Cav. Div., Sig. Co., not present.
3rd, 4th, 5th and 6th Sig. Cos. not present.
17th & 59th Cos. 5th Div. not present.
Works & Fortress Cos. and B.T.'s not present.
2nd & 3rd A.C. Sig. Cos., not present.

GHELUVELT, 29th—31st OCTOBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
23rd. Fd. Co.	1st Div.	E.	
26th Fd. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
54th Fd. Co.	7th Div.	,,	
55th Fd. Co.	,,	,,	
1st Div. Sig. Co.	1st Div.	,,	
2nd Div. Sig. Co.	2nd Div.	,,	
7th Div. Sig. Co.	7th Div.	,,	
3rd Fd. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	
1st A.C. Sig. Co.	1st A.C.	,,	

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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GHELUVELT—*continued.*

Verifications.

56th & 57th Fd. Co., 3rd Div., not present.
7th & 9th Fd. Co., 4th Div., not present.
12th & 38th Fd. Co., 6th Div., not present.
17th & 59th Fd. Co., 5th Div., not present.
3rd, 4th, 5th, 6th Sig. Cos., not present.
1st Fd. Sqdn., 1st Cav. Div. Sig. Sqdn. not present.
Works, Fortress and B.T.'s not present.
2nd Fd. Sqdn. not present.
2nd & 3rd A.C. Sig. Cos. not present.

NONNE BOSCHEN, 11th NOVEMBER, 1914.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
23rd Fd. Co.	1st Div.	E.	
26th Fd. Co.	,,	,,	
5th Fd. Co.	2nd Div.	,,	
11th Fd. Co.	,,	,,	
56th Fd. Co.	3rd Div.	,,	
17th Fd. Co.	5th Div.	,,	Detached from its own Division.
59th Fd. Co.	,,	,,	Detached from its own Division.
1st Div. Sig. Co.	1st Div.	,,	
2nd Div. Sig. Co.	2nd Div.	,,	
3rd Div. Sig. Co.	3rd Div.	,,	
3rd Fd. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	

Verifications.

57th Fd. Co., 3rd Div., not present.
7th & 9th Co., 4th Div., not present.
12th & 38th Cos., 6th Div., not present.
4th, 5th, 6th & 7th Div. Sig. Cos., not present.
1st Fd. Sqdn. and 1st Cav. Div. Sig. Sqdn. not present.
54th & 55th Fd. Co. 7th Div. not present.
Works & Fortress Cos., & B.T's not present.
2nd Fd. Sqdn. not present.
1st, 2nd, 3rd A.C. Sig. Cos. not present.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

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FESTUBERT, 1914, 23rd—24th NOVEMBER.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
3rd Co. 1st S. & M.	Meerut Div.	E.	Reliefs carried out during the period.
4th Co. 1st S. & M.	,,	,,	
20th Co., 3rd S. & M.	Lahore Div.	,,	
21st Co. 3rd S. & M.	,,	,,	

Verifications.

Meerut & Lahore Divl. Sig. Cos., not present.

NOTE.

Up to this period no units under about 100 strong have been included. This leaves out all Signal units except English Infantry Corps Sig. Cos. and Divl. Sig. Cos. Also Field Troops.

GIVENCHY, 1914, 20th—21st DECEMBER.

Unit.	Formation.	*E. *N.E. *D.	Remarks.
20th Co. 3rd S. & M.	Lahore Div.	E.	
21st Co., 3rd S. & M.	,,	,,	
Lahore Div. Sig. Co.	,,	,,	
4th Co., 1st S. & M.	Meerut Div.	,,	

Verifications.

23rd and 26th Co. not present.

1st Sig. Co. not present.

3rd Co., 1st S. & M. not present.

Meerut Divl. Sig. Co., not present.

*E.—Eligible. *N.E.—Not Eligible. *D.—Doubtful.

(*To be continued*).

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THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914-19.

EXPERIMENTAL SECTION (*continued*).

CHAPTER 9.—SURFACE LAND MINES AND TRAPS, AND DELAY FUZES.

From the earliest days of the War various devices were in use for exploding mines by some form of trap. Several methods were described and illustrated in the *Manual of Military Engineering*. These consisted chiefly of trip wires introduced amongst barbed wire entanglements. These traps, except under special circumstances, were liable to be as much a source of danger to one side as to the other, and, except on the occasions of raids into the enemy trenches, or in a withdrawal from a position, they were not used to any great extent. The necessity for repairing the wire entanglements in " No Man's Land," demolished from time to time by shell fire, did not encourage the use of traps except under certain conditions and in certain specified areas.

In raids, however, where such devices could be left in enemy trenches, or on the withdrawal from recognised positions, mines and traps were frequently used. Plate XVIII illustrates the German pattern of land mine which could be fired by wire traps and other means. Types of somewhat similar design were used to a fair extent in the British Army, and were made up in army workshops.

In 1916, the Experimental Section was called upon to devise a suitable delay fuze for raid purposes. The mine could then be concealed in the enemy dug-out or trench, and fired after the raiding party had left. Portable charges were developed from this device, and Plates XIX and XX illustrate the standard patterns with two recognised types of fuzes, the original samples of which were made by the Section. Petrol tins and oil drums were used for the purpose and filled with ammonal; the 50-lb. standard tins of ammonal supplied by Ordnance were also used for mine charges. The delay fuze, which was designed and made by the Experimental Section, consisted of lengths of ordinary safety fuze wound in various ways and reaching a maximum time of delay of about 20 minutes; and large numbers of these were made by the First and Second Armies. A series of interesting experiments were carried out in May, 1917, to determine the effect of these charges on dug-outs. The conclusions arrived at were that :—

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(*a*) Charges of 10 to 30 lbs. had little effect on the dug-out shaft itself, and in no case could the entrance be regarded as effectively sealed;

(*b*) A charge of 20 lbs. would almost certainly kill—or, at all events, incapacitate—all the inhabitants of a dug-out;

(*c*) From the point of view of the dug-outs being available for use by our own men after they had been cleared of the enemy, the results were satisfactory.

In time a demand arose for something more scientific in the form of a delay fuze. Ordinary safety fuze could not be used for long delays, and even for short delays there was a fear of discovery owing to the smell of the burning fuze.

In July, 1917, a series of experiments with clockwork mechanism was carried out by the Section. The R.A.F. had felt the need of such a fuze for special use, and the results of these trials were closely watched by the R.A.F. Staff. After a short time the fuze illustrated in Plate XXI, Fig 3, was developed, and special incendiary bombs were made up for the R.A.F. with this fuze. Although the watches used were not of good manufacture, and were not entirely suitable for the purpose, the design of the fuze was satisfactory and the principles laid down were detailed in a letter to the War Office in calling for experiments from England for the development of delay fuzes for portable charges and mines. These principles, as illustrated in the Section's clockwork fuze, were adhered to in the chemical fuze designed by the M.I.D., which was brought out to France in April, 1918, and is illustrated on Plate XXI, Fig. 2.

The delay obtained with the clockwork fuze could, of course, be accurately set by minutes up to one hour by the use of the long hand, or, roughly, from 10 minutes up to 12 hours when using the small hand.

The clockwork fuze was not developed by the Ministry of Munitions, who had turned their attention to the development of the chemical pattern as being easier to manufacture. Repeated demands by the General Staff, France, for an accurate delay fuze caused many experiments to be carried out with the chemical pattern, but accurate results were not obtainable. The fuze illustrated on Plate XXI, Fig. 2, gave hours of delay—12, 24 and 36, with intermediate six hours of delay if required. The striker was held up by a brass plug "A" kept in place by a disc of celluloid of varying thickness according to the time of delay required. Acetone in a bottle carried above the chamber behind the disc dripped into the chamber when the bottle was crushed by the screw plug "H," and the celluloid being eaten away, the brass plug was forced back by the pressure of a spring and also of the striker itself, and the striker was then released. The plug "H"

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could not be unlocked when once screwed down as it was caught by the spring pellet "K." If "A" was unscrewed, the striker was released and the mine fired. The whole fuze could not be unscrewed as it was fitted to the 3-in. Stokes bomb, and the bolt "C" slipped into the holes in the top plate of the bomb and locked it.

A certain number of these were used, but after the change from the defensive to the offensive in 1918 there was little demand for them.

Experiments carried out showed that the time of delay was very erratic and affected greatly by the temperature. This was only to be expected from a chemical fuze, and agreed with the results obtained with the German delay fuze which depended for its time of delay on the action of acid on wire.

A similar fuze was experimented with by the Experimental Section in consultation with the Director of the Central Laboratory, with a view to improving the accuracy of the delay, but the decision arrived at was that, if anything, the German pattern was more inaccurate than the British, owing to the extra cause of inaccuracy introduced by the varying tension in the wire.

The range of inaccuracy of both patterns is illustrated by the following results obtained :—

The celluloid disc in the British pattern gave a 10 per cent. variation at the same temperature. The mean time at 60° F. was halved in some cases at 120° F., and more than halved in others; and practically the time of delay increased in proportion to the rise of temperature.

The German pattern had a similar variation of 10 per cent. mean at the same temperature, but the temperature being 60° F. the time of delay was halved at 100° As an example the 72-hour delay at a normal temperature of 60° F. was increased to 103 hours at 45°, a very ordinary temperature in wet wintry weather.

The German delay fuze was introduced for use with shell fuzes for demolition only during 1918, and a description of this is given on Plate XXI, Fig. 1.

The Experimental Section carried out trials with a large number of these for determination of accuracy, but longer delays than 72 hours were not available for trial.

During 1918 samples were also obtained of an existing commercial pattern. This mechanism consisted of a clockwork device which could be set with accuracy to close a circuit at any desired time of day on any day up to seven days from the day of setting, and was used to a large extent commercially in connection with automatically-controlled lighting of streets and factories. It consisted simply of a clock and cut-out mechanism, and by electrical contact the

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circuit was closed when the time at which it was set arrived. It was not, however, introduced owing to the change in operations during the summer of 1918. It is interesting to record that from the point of view of the Experimental Section there was little demand from the troops for the use of traps or similar devices. To anticipate demands, a list of methods was prepared by the O.C. Experimental Section and was circulated in pamphlet form, but although the delay fuze was used to a considerable extent in the destruction of bridges, ammunition dumps, etc., interest in methods of laying traps was never great.

CHAPTER 10.—ANTI-TANK DEVICES.

At the beginning of 1918 there was reason to think that the Germans would employ numbers of tanks in their expected general attack, and the Experimental Section was called upon to devise a suitable contact mine for use against tanks.

It was necessary that any form of mine selected should be capable of being produced in large quantities almost immediately, and the 2-in. trench mortar bomb, of which large numbers were surplus in store, was chosen.

Experiments showed that the ordinary detonator and cap of the Newton percussion fuze were not fired by the gradual pressure exerted by a tank, but required a sharp blow. A suitable fuze was produced by the Experimental Section in February by removing the ordinary detonator, and replacing it by the standard brass lighter. The safety pin was replaced by a piece of shearing wire, and pressure coming on the head of the striker sheared the wire and allowed the spring to force the striker forward and fire the cap. This fuze is illustrated on Plate XXII, Fig. 1.

A better pattern was adapted from parts of the Mills' grenade, and is illustrated on Plate XXII, Fig. 2. The advantage of this pattern was that the shearing wire was strong and could safely bear the weight of a heavy man. There were greater difficulties, however, in local manufacture of this pattern, and the brass lighter type was generally used.

Mine fields were actually laid on a considerable part of the Third and Fifth Army fronts, but it was subsequently almost impossible to obtain definite proofs of their utility or otherwise.

In the event, the enemy used few tanks, and a few months later the British Army had themselves to cross the mine fields.

There is at least one case on record in which the Field Company, which had had the unpleasant job of laying the mines on their Divisional front in February, had the even more dangerous duty of clearing passages through the mine field when the Division advanced over precisely the same front in September. From the point of view of the Experimental Section, it was interesting

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to know that the majority of the fuzes remained active throughout this space of seven months.

Experiments were carried on for some time, the main object in view being to produce a fuze that would be fired by the pressure of a tank, but that would be safe when crossed by light vehicles or men. Several patterns were evolved, but the change in the tactical situation gave no opportunity for them to be tested practically.

In March, 1918, the Tank Corps suggested the use of rifle grenades against tanks, and various experiments were carried out, from which it was found that 1 lb. of high explosive caused severe damage to the $\frac{5}{8}$-in. armour plating of a British tank, making a hole in the plating about 1-ft. in diameter.

Trials were also made with a tin of ammonal fitted with the percussion mechanism of the Hales grenade. This gave sufficiently good results, but was not further investigated. Careful design was necessary to prevent distortion on contact, for the jar on striking the tank was so great that in all the first experiments grenades buckled up and collapsed before they had time to function.

A satisfactory pattern was produced in April, and is illustrated on Plate XXIII. This functioned if it struck the plating up to angles of 45° to the plate; it could be fired from the shoulder with an 8-in. rod, and had a maximum range of 100 yards. Under 30 yards range the flight was so erratic that it could not be depended on to function. Manufacture was taken up in England, and experiments continued, to improve the flight in the first 30 yards by the addition of tails.

When the first new German tank was captured in July, and became available for experiments, parts of the plating were found to be of great thickness, and apparently of mild steel instead of armour plating. The effect of the grenade was not as good as expected, and efforts were made to increase its effectiveness. The final pattern was filled with T.N.T. instead of ammonal, and had tremendous bursting effect, but supplies did not reach any great quantity before the change in the situation cancelled the need for them.

Various interesting experiments were carried out in connection with anti-tank defence work, in the course of which it was found that a 5-lb. tin of ammonal was sufficient to break the track of a British tank, and a simple portable charge of this kind would certainly have been made if any serious opposition had been experienced from enemy tanks.

During the final advance in the summer of 1918, various patterns of German anti-tank mines and fuzes, of more or less similar design to our own, were found, and were sent to the Experimental Section for examination.

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CHAPTER II.—ARMOUR PLATING AND AMMUNITION.

Experiments with plating and armour piercing ammunition were called for from time to time during the four years in which the Experimental Section existed, chiefly to determine the standard of penetration of ammunition, and the power of resistance to penetration of various types of armour and parapet plates.

The most important trials were :—

(i.) Armoured cars and experiments to protect the plating.

(ii.) Trials for penetration and protective facings of Japanese shields, the steel plating being made in England.

(iii.) Comparative trials between British K.A.P. and K.16 Mark VII Ammunition.

(iv.) Comparative trials between German and British A.P. ammunition.

(v.) Comparative trials with paper and Aluminium-tipped S.A.A. for effect on human flesh.

It was found as a result of experiment that body armour, sufficiently light for mobility, could not be made to resist S.AA. at decisive ranges, but sniper's body armour, which could be worn at rest and not carried into action, could be made proof down to 100 yards against ordinary, but not A.P. ammunition.

On the other hand, snipers' parapet shields of practical weights could be made to resist S.A.A. down to 50 yards, but not against A.P. ammunition.

Body armour could then only be expected to resist fragments of bombs or small pieces of shrapnel, and might be used for bombing fights, for which purpose bombing shields were, therefore, developed.

Many inventions were submitted to G.H.Q. in France and also to the M.I.D. in England in connection with materials and designs of suitable body armour, but plain steel curve plates carried in canvas or leather were never improved upon by any special design or other material. Chain mail splintered, and caused worse wounds if seriously dented, and failed for various reasons.

A shield with a covering of woodite $\frac{1}{8}$-in. thick was tested and found proof against the German bullet reversed, but its weight—20-lbs.—was considered excessive.

Tests on the German bombers' shield gave similar results. It was useless against rifle fire, but gave good protection against revolver bullets and bomb fragments.

In early 1915 it was suggested that a light shield, to be pushed along the ground on wheels, would be useful, and a vast number of inventions and suggestions were submitted, and the French made patterns of all sizes. As a result of experiment, however, the opinion was formed that no shield good enough to protect one

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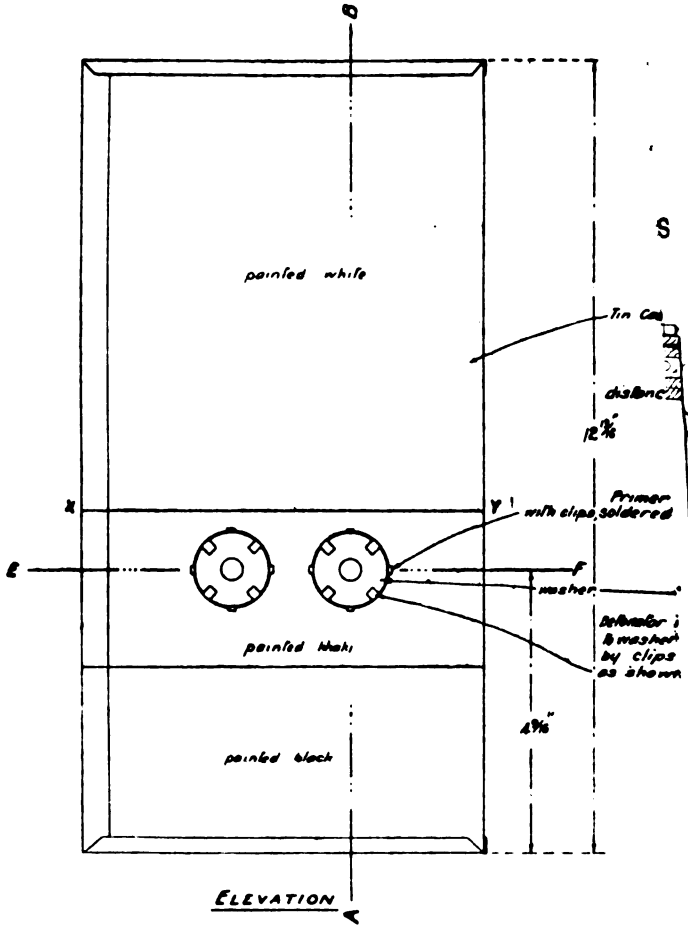

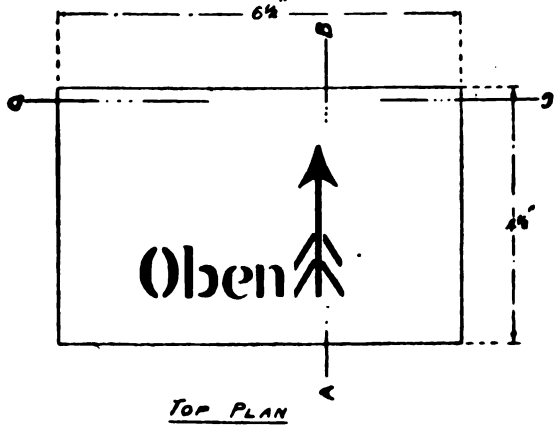

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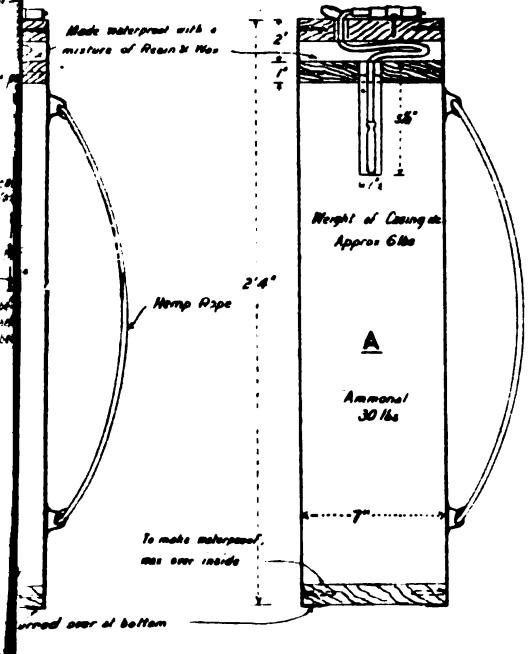
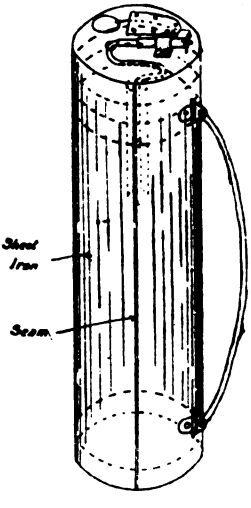
Plate XIX.

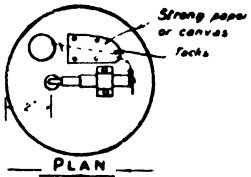
S IN THREE SIZES.





PERSPECTIVE SKETCH

Not to Scale



PLAN

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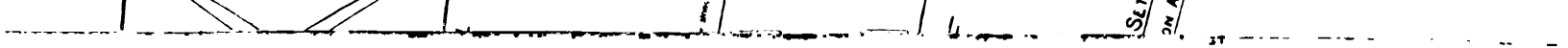

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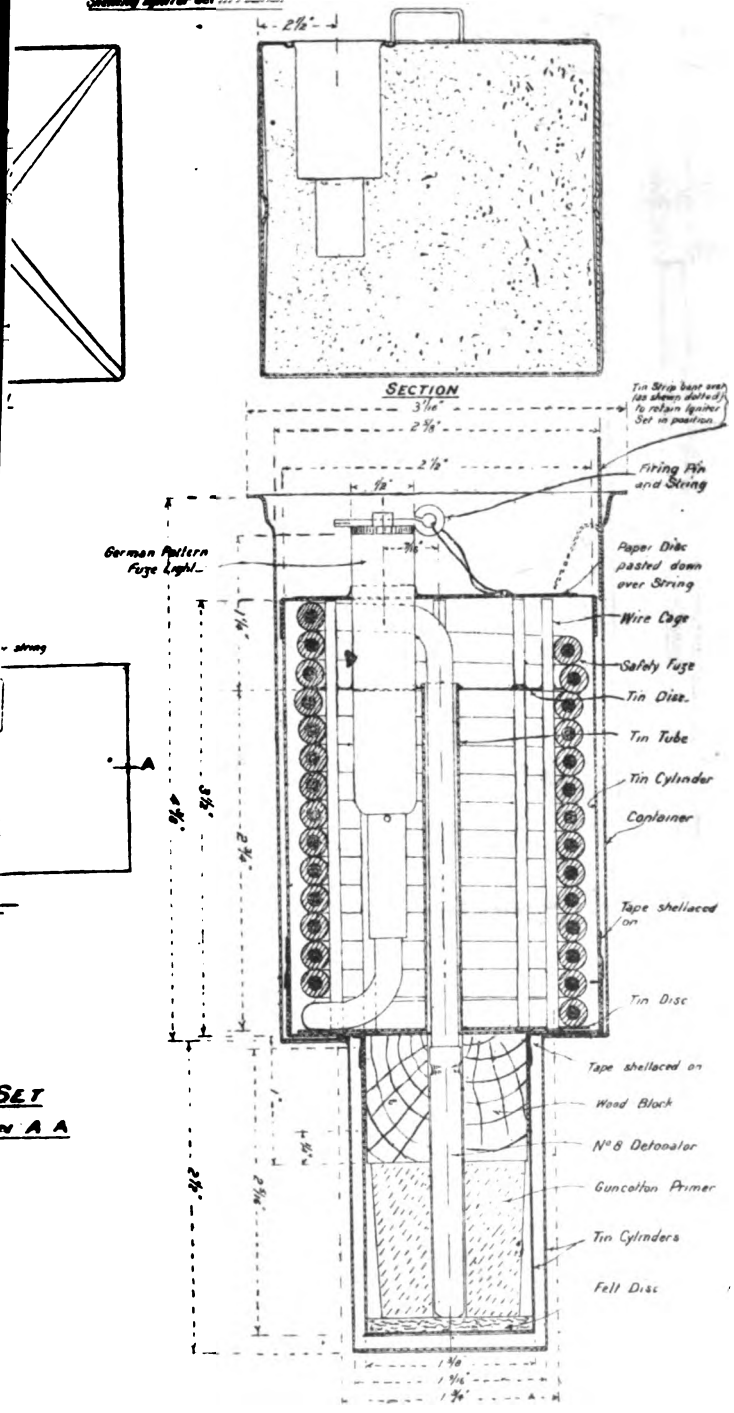
PORTABLE CHARGE

STANDARD AMMONAL TIN
Showing Igniter set in Position



SET
ON A A

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Plate XXI. Fig 1.

AY FUSE FOR 2in. T.M. BOMB.

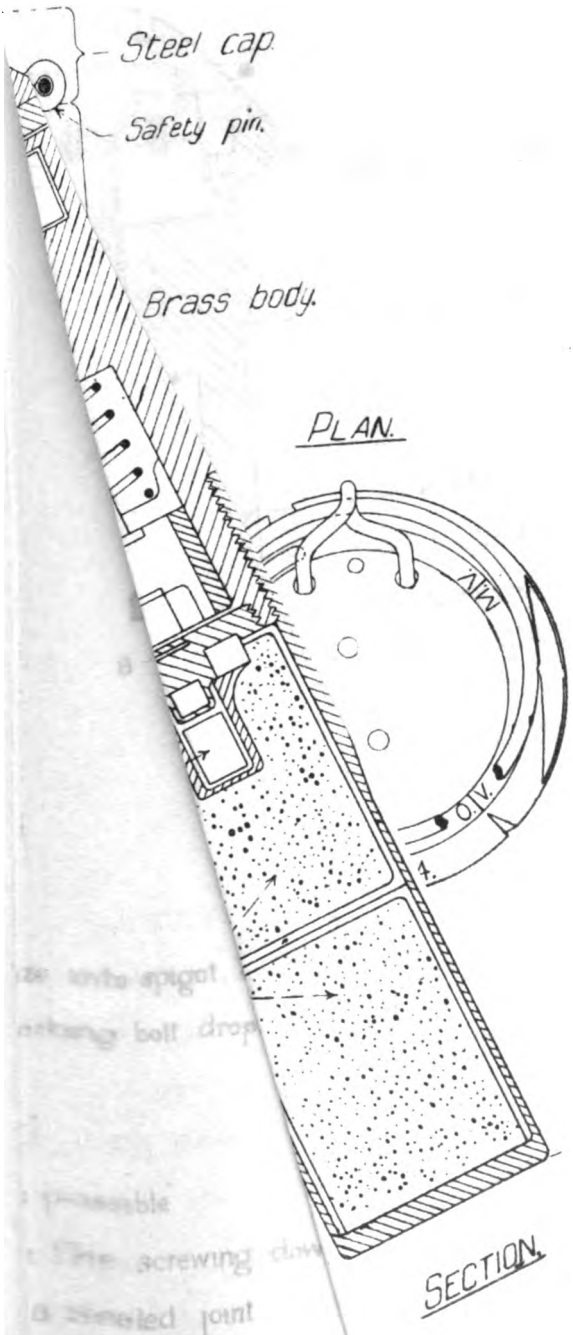

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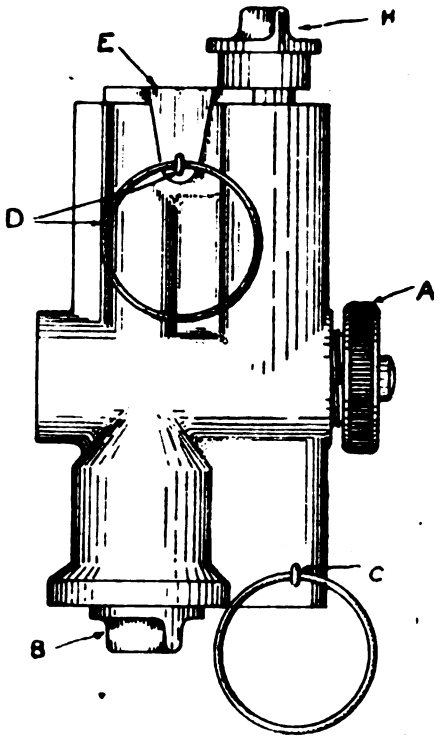
Plate XXI. Fig 2.

)N FUZE



ELEVATION

ze into spigot on head of bomb
ocking bolt drops into nearest

possible
the screwing down of H.
a sealed joint

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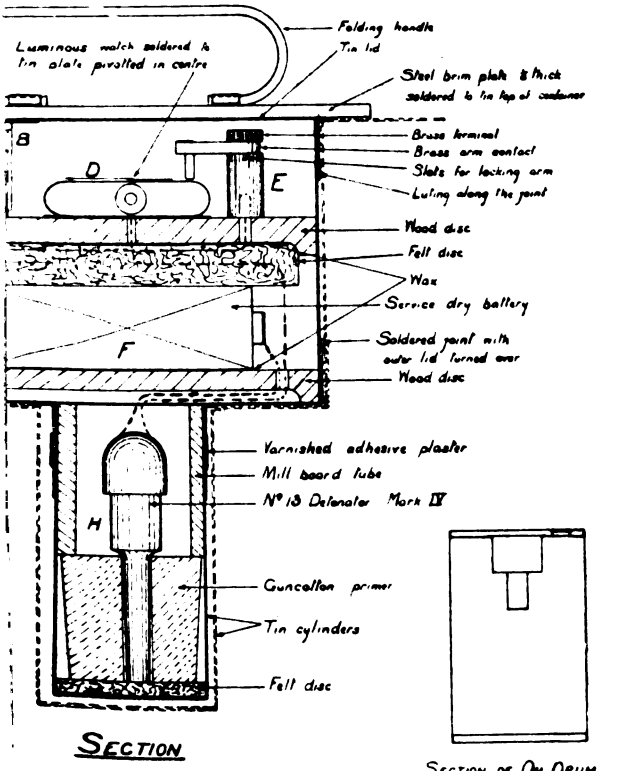
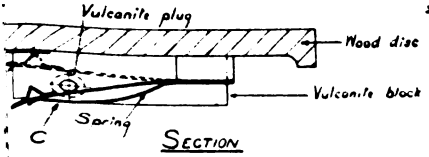
Plate XXI. Fig 3.

IN IGNITER SET FOR LAND MINES.



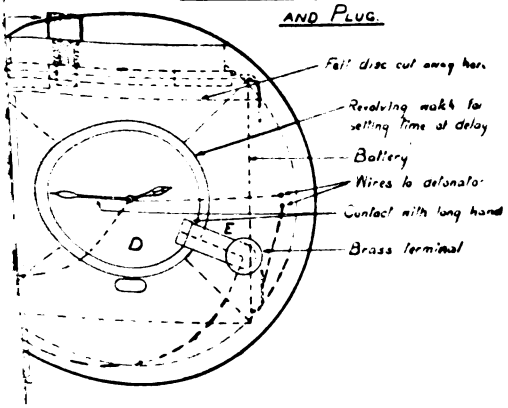
SECTION

SECTION OF OIL DRUM SHEWING MINE TUBE.



SECTION

SHEWING SAFETY CONTACT AND PLUG.



PLAN.

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Fig.

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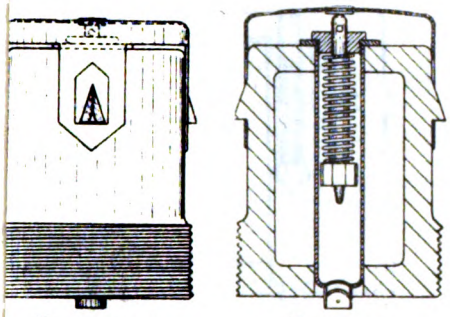
I. Plate XXII.

FOR 2-INCH T.M. BOMB.



ELEVATION SECTION.
MARK II LIGHTER.

WITH MILLS STRIKER FOR
M BOMB.

PATTERN.

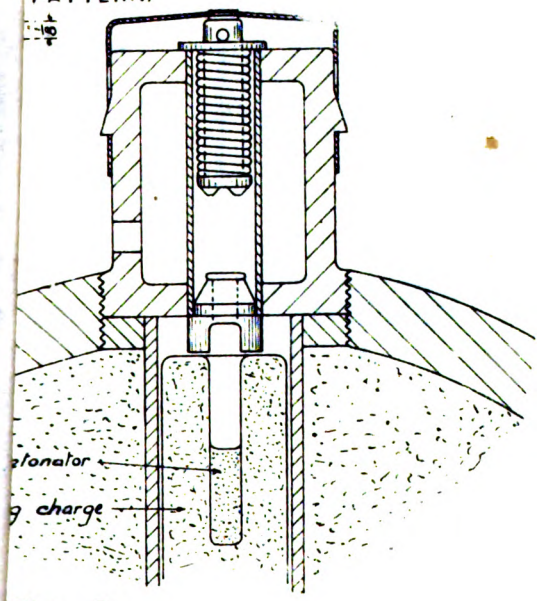


Fig. 2.

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man, which could be pushed on wheels, was light enough to be pushed, by less than two men.

An inventor at G.H.Q. submitted a design to the Experimental Section, and this shield, known as the "Van der Weyden," was made principally in order to demonstrate the truth of the above opinion. The inventor claimed that, if made and balanced like a wheel barrow, the weight when lifted would come near the wheels and so be easy to push along. Also that in this position it protected the man, and that when dropped down over him the plates could be so sloped as to defect the bullets, unless fired across the line of his direction. Against flanking fire it was useless, which was the case with most of such devices.

The vehicle when cut down to a minimum weighed 1 cwt., and no one man with his equipment on could handle such a protective shield, except under the best conditions on smooth ground.

Shields for machine guns were considered from time to time by the Experimental Section, and a sample was made which had a sliding plate with a loophole, through which the machine gun projected, and which ran on rollers while the gun traversed. It was large and cumbersome, and could only be used in trench warfare; also it was always conspicuous. After about 50 had been sent out and tried, reports were unanimous that they were too cumbersome and did not give sufficient protection.

The whole question of providing shields for machine guns was a very difficult one, as the conditions required for artificial protection are antagonistic to the important tactical considerations of invisibility and mobility. It was clear that such shields could only be treated from the point of view of trench warfare, and in this they were finally rendered unnecessary by the development of "pill-boxes."

The Experimental Section was called upon in the summer of 1918 to demonstrate to a National Commission that none of the types of ammunition in use by the British Armies in France were explosive. Trials were carried out with sample boxes of all kinds of ammunition sent up from the base, all types in use being fired, and the fragmnts collected and examined.

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it is obvious that it pays to be generous in the original layout, as regards piping. Reservoirs and filter-beds can be added to, or duplicated, at a later period, fairly easily.

It should be unnecessary to recapitulate here the qualities of a good water. The two essential requirements are that it should be free from pathogenic bacteria and from poisons.

The analysis of the various possible sources of supply is a job for the chemist ; but the engineer must decide which source of supply he will utilise, and in this he is very largely guided by the comparative costs. Experience in the War proved that a potable water could be extracted from the most unpromising supply, and a source of water must not be rejected simply because it is contaminated with sewage. Will the cost of purifying a near-at-hand foul water exceed, or be less than, the cost of laying a long pipe line to a distant uncontaminated source ? This is the question that the engineer must answer.

In the case of military waterworks, there is another factor besides cost. If the cantonment is of the nature of a fortress, it may be essential that the water supply should be inside, and not drawn from an external source.

Having decided on the source of supply, it now remains, from consideration of its chemical and bacteriological analysis, to decide in what ways it is to be purified and rendered fit for use.

Suspended solids are removed by sedimentation, though in nearly every case this slow process is artificially hastened by the addition of a coagulant, such as alumino ferric. In fact, if there is much colloidal matter in the water, coagulation is essential. In any case the use of a coagulant hastens the action, thus permitting the use of smaller tanks.

At many plants, where the water is filtered after coagulation, trouble is caused by some of the gelatinous coagulated matter passing through into the effluent. [4] Recent investigations have shown that this is due to using an excess of alum, when an easily broken " floc " is formed, and this readily passes through the sand. The " floc," when microscopically examined, should consist of just sufficient of the hydroxide to bind the solid particles together, and no more.

Another coagulant sometimes used is ferric hydroxide. The crude water is circulated through scrap iron, and then aerated, when the iron dissolved is precipitated as ferric hydroxide.

The oldest method of removing bacteria from the water is by slow-sand filtration, though this was only discovered by accident, the first filter being made solely for the purpose of removing suspended matter.

4 *Engineering News Record*, May 1st, 1924, p. 768.

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M.E., Vol. VI,[5] states that a square yard of filter-bed is required for every 675 galls. to be filtered in 24 hours. This is a rather high rate of filtration, and the common practice is not to allow a greater rate than 450 galls. A too rapid flow leads to the formation of cracks in the sand, uneven settlement, and unreliable filtration.

Considering this particular scheme, the filters must be able to deal with 1,200,000 galls. a day.[6] An area of 2,600 sq. yds. of filter-beds will, therefore, be required, without allowing for extra beds for use when others are laid off for cleaning, or for the paths, etc., between the beds, and space for washing the sand. Land is often expensive, and the large amount of sand required may have to be brought from afar.

These objections led to the introduction, fifty years ago, of rapid mechanical filters. A battery of these to deal with this quantity of water would occupy only some 600 to 700 square feet, costing about one-third of the price of slow sand filters (in England).

In the tropics, land and labour are usually cheaper than at home, and, therefore, these factors do not carry such great weight. Also the price of the transportation of the mechanical filters must be considered. Nevertheless, it is believed they would usually be cheaper in first cost, and certainly cost less in maintenance.

There is, moreover, another advantage of the mechanical filter, and that is that it is possible to distribute the flow of water more evenly, with less likelihood of channels forming in the sand, through which the water can pass without being properly filtered.

Except in the case of the Candy Compound Filter, in which suspended matter is first removed in a coarse grit pre-filter, all suspended matter must be eliminated from the water before it is passed to the filters. If this is not done, the filters will clog very rapidly, and need very frequent cleansing.

The usual method of cleaning is by reversing the flow of water, at the same time stirring up the sand by means of revolving scours; the process taking about a quarter of an hour. This method is not always successful over long periods, and more drastic methods are necessary.

[7] Just before the War, it became necessary to add to the Berlin water-supply, and sixty "Bollmann" filters were installed. These much resemble the ordinary types, but with the addition of an "injector" at the bottom. Water is forced through the injector, sucking with it the sand, up the injector discharge, which is a vertical pipe in the centre of the filter, terminating above the surface of the sand. The sand is very thoroughly scoured in its rapid

5 p. 207.
6 Viz., p. 10, paragraph 2.
7 *Engineering News Record*, September 13th, 1923, p. 428.

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passage through the injector discharge, and the dirty water is removed from the top of the filter. This method of "spring cleaning" is resorted to about once a month, the usual back-washing being employed in the interim.

One of the great difficulties in working a batch of mechanical filters is to ensure that each unit does its fair share of work, and that the proper rate of flow is not exceeded. There is not space here to consider the various automatic regulators that have been devised: one is described in the *Engineer News Record* of September 13th, 1923.

The efficiency of a filter, from the bacteriological point of view, depends entirely on the integrity of the gelatinous film on the top of the sand. This film, formed of algae and zooglea in the case of a slow-sand filter, and of aluminium hydroxide in the case of a mechanical filter, is never more than a fraction of an inch thick, and is easily broken. No form of filter can absolutely ensure that no bacteria will pass into the effluent, and a few bacteria may, under suitable conditions, soon multiply rapidly; and this is especially the case in the warm waters of the tropics. Where, therefore, the source of supply is liable to any degree of sewage contamination, further means of purification should be resorted to. The most usual method is chlorination, a method that has been widely practised in America, and which is being gradually adopted in England.

Sterilisation by gaseous chlorine is the most efficient and exact method, owing to the purity of the gas as compared with its salts. But the great objection to it is the prime cost of the apparatus, which is intricate, needing skilled supervision. The cost of the apparatus would be practically the same, whether it is required to deal with 10 millions or one million gallons a day; and, therefore, this method cannot be recommended for use in a comparatively small installation, such as that under consideration.

Of the chlorine salts, bleaching powder (calcium chloride) has been most widely used, and is the cheapest. It is more trouble to make into a solution, and deteriorates very rapidly in a damp climate; though this defect could be overcome by obtaining it in sealed tins. Sodium hypochlorite, in the form of a solution known as "Eau de Javelle," and sold as "Chloros," is also used. Some engineers maintain that, in germicidal properties, it is better than chlorine or bleaching powder, and it is certainly more convenient to use than the latter; but it is a little more expensive. Chloramine is another sterilising agent, prepared by adding ammonia to sodium or calcium hypochlorite.

Various simple devices for measuring the quantity of chemical to be added to the water can be bought, or easily constructed. The essential is that the possibility of the apparatus failing to func-

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tion, and thus allowing unsterilised water to pass, must be reduced to a minimum. The amount of chemical is regulated according to the flow of the influent. It is very important that the attendant should be able to see, at a glance, if the feed is working properly.

An excess of at least half part of chlorine in a million must remain in the effluent, and, as this is only effective as a germicide after five hours' contact, it is much safer to allow an excess of up to two parts in a million, which kills all bacteria in half-hour. The excess is then removed by a reducing agent.

Sodium and potassium permanganate are useful re-agents which have been used for years. Sulphur di-oxide, which has to be stored in a cylinder as a compressed gas, carbon, sodium bi-sulphate and hydrogen peroxide are also used.

But if the water has to flow through two or three miles of pipe before being drawn off, de-chlorinisation is effected without the use of any re-agent. An excess of two parts in a million is reduced to half-a-part in a mile or so of pipe. This excess of chlorine has, moreover, been repeatedly proved to be the best means of preventing water containing iron from developing " rustiness," and of preventing the pipes becoming fouled with " crenothix."

De-chlorinisation by carbon is carried out in the " De-Chlor " Filter, a battery of which is in use at Reading. A solution of bleaching powder is admitted, through a regulator, into the top part of the filter, where it is in intimate contact with the water for half-an-hour. The water then passes through a bed of carbon, which removes the excess of chlorine. The carbon can be used for several months, and can then be revivified at a very small cost. The rate of working is 32,000 galls. per square yard per day. As the filter units (17-ft. x 8-ft.) deal with 200,000 galls. a day, a battery of six would be needed for our scheme.

Two other methods of sterilisation must be mentioned *en passant*—ultra-violet ray treatment and purification by ozone. Both are hardly past the experimental stage, and both depend on cheap power in order to be a commercial proposition.

The latest invention in the realm of water purification is the stream-line filter, which was first exhibited in 1923 at Olympia. The action of this filter, which is very simple, has already been described in the *R.E. Journal*. It should be noted that it is a case of real mechanical filtration, not depending on the presence of a skin, formed by bacteriological or chemical action. The largest unit shown at Olympia was a battery of sixteen vertical filters, with a rated capacity of 10,000 gallons an hour. The cleansing of these filters is done, either by means of a reversal of flow, or by scouring out the influent tubes with a piston. As they need very frequent cleansing, the water should be first passed through a pre-filter.

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The writer has been unable to find any record of this novel type of filter having yet been installed as a commercial proposition, but it seems that it should have an extended use. The cost of such an installation is comparatively cheap, and it would probably cost less in maintenance and labour than a bleaching-powder plant.

To recapitulate: the greater portion of suspended matter is removed by sedimentation and coagulation, the remainder of the solids, taste and smell, and most of the bacteria are removed by filtration; finally, chlorination kills the few bacteria still in the water. Practically every water will need treatment by sedimentation and filtration, a good proportion will be advisedly chlorinated, some will need further treatment for excessive hardness.

The problem of water softening is much more urgent in manufacturing towns than in residential ones. For domestic purposes a fairly soft water is undoubtedly desirable, but cannot be said to be really necessary. The funds available will decide whether it is possible to treat the water for hardness.

Two methods can be employed, the old soda-lime treatment, or the Permutit system. As regards relative cost, when the permanent hardness is high compared with the total hardness, the latter will be usually the cheaper, but if most of the hardness is temporary, the former will probably be the cheaper.

Unless the water was of exceptional hardness, funds would not generally allow of a cantonment water supply being softened. But if there is a central power house and workshops, this should have its own softening plant.

The water, purified and treated as necessary, is now ready for distribution; and, for this purpose, is first passed into a service reservoir.

The function of this is three-fold. Firstly, to provide a fire reserve; secondly, a reserve against a breakdown of the pumps, or a break in the pipe line from the impounding reservoir; and, thirdly, to maintain a constant head in the mains.

The Water Supply Manual of 1909 lays down a fire reserve equal to one day's consumption, and a breakdown reserve equal to two days' consumption. Other books also suggest a "normal" capacity of three days' consumption.

That such rules of thumb are practically valueless can be seen from a moment's thought. The reserve that should be kept in hand against a break in the line from the reservoir depends entirely on the distance of that reservoir from the town, and on the number of sources of supply. A town of 10,000 inhabitants might quite conceivably need a larger reserve than one of double that population. The engineer must first of all decide how long it would take to repair the worst break in the line (or breakdown of the pumps)

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that might reasonably happen: the reserve required will then equal the amount of water that would be consumed in this time.

As regards fire reserve, Burton gives a formula. [8] $Q = 200\sqrt{P.}$, where Q is the quantity of water in cub.-ft. required as a fire reserve, and P. is the population. With a town of 20,000, Q is 176,000 galls. (about 1/5 of the day's supply). This quantity is sufficient to keep 20 hydrants at work for about 70 minutes, which should be sufficient. This formula, like all other empirical formulæ, should be used with caution. Each case must be considered on its merits.

We have noticed that the third function of a service reservoir is to maintain a constant head in the mains. If the pressure in the mains is allowed to fall, a vacuum will be formed in the higher parts of the system, and this will lead to an infiltration of surface water, and possibly sewage, with disastrous results. This was one of the great objections to the "Intermittent Service," now never seen in permanent work.

In the case of a pumped supply, a stand pipe is often substituted for the service reservoir, to save the cost of constructing the latter. The fire reserve must then be provided for by a stand-by pumping plant.

The position of high ground will determine whether the reserve is to be installed in one large reservoir, or in several smaller ones. If one portion of the town is at a considerably lower level than the remainder, it may be impossible to maintain a good working pressure, with a single reservoir, in all parts of the system. In such a case special arrangements must be made. The alternatives open to the engineer are to install separate service reservoirs for the different parts of the town, or to employ break-pressure tanks, or pressure-reducing valves.

Service reservoirs should be covered. Although open air storage improves bad water, good water deteriorates in open reservoirs, owing to the growth of algae and other micro-organisms that need light. The water also will keep cooler (and really cool water is a great comfort in the tropics), and dust and dirt will not get in.

From the service reservoir the water passes into the town main. The distributing mains should be so arranged that there are as few dead-ends as possible. If carefully thought out, this "reticulated" layout will not require a greater weight of pipe than the "tree" pattern, as, although there will be a greater length of pipe, the pipes can be smaller, as any point will be supplied from at least two directions. The advantages of the system are that it ensures a continuous flow in the pipes; and that, in case of a large fire, it enables a great portion of the whole water supply to be concentrated at the threatened point.

8 *Water Supply of Towns*, p. 212.

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The size of the mains is the next consideration, and to determine this it is necessary to decide on the greatest rate at which they will have to deliver water. The [9]figure of 40 galls. per head per day is an average for the whole year. Owing to seasonal and daily variations, the mains will have to deliver at a much greater rate than this.

It is obvious that more water will be used in summer than in winter, and for a few days the consumption may rise to 50 per cent. above the average, and this maximum consumption must be allowed for.[10]

The demand varies throughout the 24 hours, being negligible at night, and maximum during the morning. The usual practice is to design the mains to discharge 50 per cent. of the maximum daily consumption in six hours, or a maximum flow during each of these hours at 8⅓ per cent. of the daily flow. Owing to the greater diversity in the habits and occupations of a large town, this daily variation is less than in the case of small towns. Thus the [11]*Water Supply Manual* (dealing with a battalion barrack supply) says that the mains should be capable of delivering the whole day's supply in eight hours, a maximum hourly flow of 12½ per cent. of the daily flow.

As the habits of the soldiers in a cantonment are much more similar than those of the civilian inhabitants of a town, the daily variations will be greater in the former case. To keep this variation in bounds, and thus to save the use of very large pipes, a judicious supply of house cisterns can be installed, but sparingly, as any cistern is liable to contamination. Water for drinking and cooking purposes, or that might be so used, should invariably be drawn direct from the main. Cisterns should not be on the roof, where they get dirty, and the water hot, but underneath it, in some easily accessible place. The design of barracks, with latrines and ablution houses grouped together, especially lends itself to cistern supply.

The case of towns is different. It is impossible to arrange for a strict water discipline to ensure that cisterns be kept properly clean as with cantonments; and the necessity for them is not nearly so great. They should be installed in only large houses and hotels, or in houses far removed from the main.

In the particular scheme being considered, the average daily flow (at 40 galls. per head per day) will be 800,000 galls. Adding 50 per cent., the maximum daily flow becomes 1,200,000 galls. Assuming a maximum hourly flow equal to 8⅓ per cent. of the

9 Viz., p. 256.

10 In the case of places very near the Equator, this consideration does not arise, winter and summer being nearly the same.

11 *Water Supply Manual*, 1909, p. 51.

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daily flow, the mains must be designed to deliver 100,000 galls. an hour, or 1,666 galls. per minute.

As each half of the ring main supplies only half of the town, it need only be able to take half this amount, or 800 galls. a minute.

In the design of the whole system, the question of fire protection must be borne in mind. The necessary fire reserve has already been considered, but it remains to be decided at what rate it is necessary to supply water for this purpose, as on this the size of the mains may depend.

Two fires at the same time, each requiring five hoses, is not an unreasonable suggestion. Each hose requires 120 galls. a minute, and, therefore, the main must carry 1,200 galls. a minute. As the two fires may very possibly occur in close proximity, each half of the ring main should be capable of delivering this amount. It will, therefore, be seen that fire requirements are the deciding factor in this scheme—as in all small schemes.

Some writers[12] go to the length of suggesting that the principal mains should be able to carry the fire provision (a minimum of 1,200 galls. a minute) in addition to the absolute maximum consumption—*i.e.*, in this case, 2,000 galls. a minute. This the writer cannot help thinking is over generous, leading to unnecessary expense. The great majority of fires occur at night, when the domestic consumption is very small; the mains have, moreover, already been designed to carry 50 per cent. more than the average daily flow, and they will only be worked at this rate for a very few hours during a few days of the year.

Therefore, if the principal mains are designed to carry 1,200 galls. a minute, there should be a reasonably ample supply in case of fire. With the usual hydraulic gradient met with, a pipe of 14-in. to 16-in. diameter would be necessary.

Hydrants should be spaced at 100-yard intervals. It is, therefore, evident that the smallest main will probably have to supply two hydrants, each of which will consume water at the rate of 120 galls. per minute. A 4-in. main will usually be sufficient, with the heads normally used. This is absolutely the smallest main that should be allowed in permanent work, owing to the rapid incrustation of a smaller pipe. American practice favours 6-in. as the smallest permissible diameter, and this is certainly more desirable, if the funds available will permit the extra expense.

The head in the mains should everywhere be such that the fire hoses can bring a stream of water to bear on the roofs of the houses. This will, of course, vary with the height of the buildings in use: a 40-ft. head would be sufficient for two-storied buildings. In no case must the head in the mains be less than 10-ft. But it will

12 *e.g.*, Burton, p. 196, *The Water Supply of Towns.*

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not always be possible to arrange for a sufficient head for fire fighting purposes, especially if six or eight-storied buildings have to be catered for; and, in this case, the extra pressure required must be supplied by fire engines. A head greater than 200-ft. should not be allowed, as this brings an undue pressure on the house fittings.

Pipe calculations are bound to be very much guesswork. A carefully-designed pipe layout is of much more practical use than a lot of intricate mathematics; and it should always be borne in mind that putting in a slightly larger pipe than necessary is a fault on the right side.

Pipes can be either of cast or wrought iron, steel or reinforced concrete. Wrought iron is ruled out of court by its cost; and, in permanent work, its use is confined to house connections.

The advantages of steel pipes over cast iron pipes are many. They are stronger, made in longer lengths, which reduces the time and labour expended in jointing, and very much lighter. In a tropical station, removed from the sea, this question of weight and transport might be of paramount importance. Steel pipes are also cheaper.

But there is one very serious drawback to steel pipes, and that is that they are apt to suffer very badly from corrosion. The most notable instance of their use was in the construction of the Coolgardie pipe line, a 30-in. main, 350 miles long. The pipes were coated with a mixture of coal tar and Trinidad asphalte, but in five years internal corrosion had reduced the discharging capacity from 14 to 53 per cent. in various sections. On the other hand, 15 miles of cast iron pipes, 12-in. to 20in. in diameter, put in at Versailles 250 years ago, are still in use and working efficiently. At the Tay Bridge, at Dundee, the same identical water is carried by a cast iron pipe without corrosion, and by a steel pipe which so corroded as to render renewal necessary. These examples are given to show that experience points to the fact that steel pipes are much more liable to corrosion than cast iron ones. At the same time, there are numerous examples of steel pipes giving satisfactory service, and cast iron pipes have also perished.

The cause of corrosion is not yet accurately known: the chemists have accused carbonic acid, hydrogen peroxide and electrolysis of being responsible. The nature of the water undoubtedly has something to do with it, but that it cannot be the only cause is conclusively shown by the experience at the Tay Bridge.

In view of the manifest advantages of steel pipes, particularly in places where transport is a difficulty, their use should be certainly considered; but it would be unwise to adopt them without careful consideration of the character of the water. Previous experience in the locality will be the most useful guide. Whether cast iron or steel pipes are used, they should invariably be coated with a protective coating, inside and out. Dr. Angus Smith's composition

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is very widely used, and lately cement is finding favour. This latter method was highly recommended at the Royal Sanitary Congress, 1923.

Cast iron pipes made by centrifugal action are a recent development, and should be in wide use in a few years' time. As we have seen, one of the great objections to cast iron pipes is their weight; and this is diminished to the extent of 25 per cent. in the case of Stanton "spun" pipes; and they are more free from blow-holes and defects. At present they are only made up to the 12-in. size.

Reinforced concrete pipes are also now made, from 4-in. size upwards, but the writer has been unable to find any records of their capabilities. As cement is used as a protective covering for iron pipes, it seems probable that concrete pipes will not suffer from corrosion.

We noticed that one of the chief reasons accounting for the widely differing consumptions of various towns was waste. A fact not always realised is the immense amount of water that runs to waste through a small leak or hole. A tap steadily dripping will easily waste water at the rate of a gallon an hour. Assuming 3,000 taps in the cantonment, and that 10 per cent. are leaking, 7,200 galls. will daily run to waste. A hole of $\frac{1}{8}$-in. diameter, under a pressure of 45 lbs. per square inch, will pass 3,840 galls. a day. It can be thus readily understood that the water wasted can soon amount to 50 per cent., or even more, of the consumption, if leaky fittings and mains are not repaired.

The best method of reducing waste is not to employ cheap fittings and pipes, but to carefully supervise the pipe laying and to ensure that the joints are water-tight, and to test all mains before the trenches are filled in. Cheap materials are false economy.

But the best fittings and pipes are still liable to faults, and arrangements must be made to detect leaks. This is done by dividing the town into wards that can be shut off by means of stop-cocks. A recording meter, such as the "Deacon" (the Venturi or other inferential types of meter are not suitable, as they do not function if only a small quantity of water is passing) is installed immediately below the service reservoir. During the early hours of the morning, when an infinitesimal amount of water is being used, a turncock closes the various stop-cocks in order, at special times. The chart recorded by the meter will then show the various amounts of leakage in each ward.

The leaks are then definitely located by inspection of the road surfaces for signs of moisture, and by acoustic means, using a stethoscope or aquaphone.

In cantonments a strict water discipline should be enforced. In towns waste is undoubtedly much reduced by installing a house-to-house water supply, charged on meter registration. This

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naturally makes the householder careful. But the system cannot be recommended, as it is an inducement to people to use less water than they should, to be miserly to the detriment of the public health. In England, the only town so served is Malvern, though in America and on the Continent the system has found more favour.

Many householders seem to imagine that a continually running tap keeps the drains "sweet." This is a fallacy. What is required is not a continual ineffectual dribble, but a large flush of water from time to time. This is provided by the W.C. cisterns, which should be large. In some towns the installation of W.C. cisterns of more than two-gallon capacity is forbidden, but this is a very bad policy: it saves water at the expense of sanitary drains. Unless the house drain is very short and with a good fall, a two-gallon flush is not sufficient. In the tropics a generous flush of the drains is especially important.

This is the dividing line between water supply and sanitary engineering.

It will have been noticed that the tropics do not present any startlingly new problems to the engineer, and that the differences between water supply at home and in the tropics are not very great. In both the object is to provide an ample supply of good water.

In conclusion, it cannot be too strongly urged that true economy is attained, not by cutting down the supply or by saving money on necessary purification, but by the adoption of all means that will prevent waste.

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THE TRAINING OF THE REGULAR OFFICER IN AUSTRALIA.

By C.H.F.

In these notes it is intended to describe briefly the training in particular of the officer who becomes, and is, an officer of Engineer or Signal Units. It is not practicable to entitle the notes "The Training of the Regular Sapper Officer," for the reason that, with a few exceptions, principally in the Works Branch, all Officers serving with Engineers and Signals are officers of the Staff Corps, a Corps formed in 1921, to which the majority of the Regular Officers then serving were transferred, and in which all young officers are now commissioned.

The Staff Corps was formed in order to regulate promotion among Regular Officers; previously these had taken promotion in their Corps, *i.e.*, the "Administrative and Instructional Staff," the Gunners and the Sappers respectively, with the result that many anomalies had occurred, officers of the two latter Corps finding themselves junior to officers of the "A. and I. Staff" of many years' less service.

There is but one avenue of entrance to the Staff Corps, that is, through the Royal Military College of Australia, an institution founded at Duntroon in the Federal Territory in 1911, under the advice of Lord Kitchener, for the initial training of young officers.

Entrance to the Royal Military College is obtained normally by the passing of the public examinations held annually throughout Australia.

Practically every boy (and girl) in Australia who desires a decent education passes (or attempts) one or both of these examinations, which are known as the "Junior" (or "Intermediate"), and the "Senior" (or "Leaving") Public Examinations. These examinations are held by the Universities of which there is one in each State in Australia.

A candidate must be between 16 and 19 years of age on joining the College, and the College course covers a period of four years. In certain special cases, entrance of youths over 19 years is permitted, but such cases are rare.

At the end of the third year of any particular "batch," certain cadets are selected, according to suitability and (to a certain degree) their own desires, for allocation to particular Arms—*e.g.*, Cavalry,

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Gunners, Sappers, Flying Corps—and during the fourth and last year of their cadetship, they specialise along the particular line required.

In selecting officers for allocation to Engineers, great stress naturally is laid on their knowledge of mathematics and kindred subjects, as well as on their natural or disclosed aptitude for the work.

Having graduated on completion of his fourth year, a cadet is commissioned as Lieutenant in the Staff Corps, and it is at this point that the technical training of the budding Gother Mann really commences.

The following is a brief resumé of the courses and training to be undergone by the young officers commissioned on graduation :—

(1) Regimental duties, Administration, "Q" and Ordnance matters ; one month.

(2) Attachments :

(*a*) First period, to the Headquarters of an Infantry Brigade, under the supervision of the B.M., to obtain a general knowledge of Organisation, Administration and Training ; one month.

(*b*) Second period, to a Battalion Area to study Area work, under the supervision of the B.M. and Area Officer ; five or six weeks.

(NOTE.—An "Area" is that from which Trainees under the Compulsory Service Act are drawn for the Citizen Forces. A Brigade Area consists of four Battalion Areas and normally supplies recruits for a F.A. Brigade, a Field Company, four Battalions, and a moiety of other Divisional Troops.)

During either (*a*) or (*b*) attachments young officers attend a camp of continuous training, usually as an "attached officer" to a unit of the Citizen Forces.

(*c*) Third period, to a unit of the arm to which the young officer is allocated.

In the case of officers allocated to sappers, this attachment is to Headquarters, Divisional Engineers or Divisional Signals, for a period of two months.

Thus, within six months after graduating in December, the young officer has acquired a certain knowledge of the "machinery" of the Force, particularly in regard to the working of the Compulsory Clauses of the Defence Act, and the corresponding Regulations under that Act. This knowledge is essential, as the majority of officers, even those posted to the Technical Arms, will become Adjutants of Units or formations, *e.g.*, Divisional Engineers.

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Young officers allocated to Field Engineers or Signals continue their attachment to Divisional formations as above, until such time as they are posted to a further technical training, usually within some six or eight months—*i.e.*, in the first quarter of the following year.

In the case of those allocated to Field Engineers, this further training consists of two years at either Sydney or Melbourne University. The standard of knowledge required for graduation from the Royal Military College is accepted by the Senates of these Universities as being equivalent to the first and second year Engineering Course, and the young officer, therefore, enters forthwith practically on his " third year " of that course.

Two years at the University are thus allowed at Commonwealth expense, the young officer meanwhile receiving the pay of his rank and being posted nominally for duty to a formation in either New South Wales or Victoria. Actually he does little, if any, military duty, his energies being devoted to study.

Usually, the degree of B.E. is gained at the end of two years—*i.e.*, at the completion of the normal four-year University Course, and three years after graduation from the College.

Failures to graduate have been few—in the only case within the writer's recollection the failure was not of a serious nature, and the officer concerned was retained in his " nominal " posting for another year.

During this year he became responsible for the University charges, and his military duties had to be performed, instead of being merely nominal. The wisdom of this procedure was justified by his " pass " at the end of the year.

Young officers allocated to Signals are lent to the Postmaster-General's Department for two years. They are posted " nominally " to Signal units during this period and draw military pay. The Postmaster-General's Department will not accept responsibility for any expenses incurred except where these officers are actually performing duties for members of the Postmaster-General's staff.

During attachment they conform to the regulations of the Postmaster-General's Department as regards hours, leave, duties, etc. Any breach of discipline, however, is reported to the Defence Department.

Monthly reports are forwarded by heads of Departments in order that the suitability and progress of each officer may be continually under review.

The Postmaster-General's Department have, since its inception, displayed an active interest in the course. They will at all times listen to suggestion from officers in training and assist in every way in giving them a sound practical knowledge of their telephone and telegraph practices.

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It has been found that two main advantages are derived from the course. The first would apply equally to the Home Forces, while the second is peculiar to Australia.

(1) The officer gains a practical knowledge of the installation, maintenance and operation of those heavier systems of communication employed behind divisions.

(2) The bulk of Signal personnel of the Citizen Military Forces are drawn from the Post Office and consist mainly of junior operators and mechanics, and consequently an officer who has passed what they term a "Junior Engineers' Course" is looked up to with some degree of respect.

The course comprises the following work :—

(*a*) Telephone Equipment—9 months :—

(1) Workshop experience, including use of tools, assembling and repairing of instruments and minor bench work.
(2) Test room work.
(3) Testing of materials and instruments.
(4) Trunk line equipment, including superimposed systems.
(5) Installing subscribers instruments.

(*b*) Telegraph equipment—12 months :—

(1) Telegraph operating—preliminary instruction.
(2) Operating actual telegraph circuits.
(3) Installing apparatus, including duplex wheatstone and multiplex apparatus.
(4) Circuit diagram, plans and specifications.

(*c*) Line construction—3 months :—

(1) Metropolitan gangs.
(2) Jointing.
(3) Country Survey.

Sections (4) and (5) of part (*a*) include work in C.B., Magneto, and Auto Exchanges.

Four officers have completed this course and two are undergoing instruction.

One officer completes and one commences annually.

Officers for Fortress Companies are drawn from those possessing the B.E. degree, and are not posted to such units until that degree has been obtained.

Finally, the Staff Corps Officer allocated to Engineers or Signal Units will go to England for one or two years' instruction with the R.E. or R.C.S., as may be required.

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This tour of instruction will usually take place after the young officer has spent a year or so with units in Australia, in order that he may be more capable of benefiting by a study of British methods and conditions.

Up to the present, the scheme is of too recent origin to have allowed of this final addition to the training of the young officer.

The following Table summarises the periods of Training and shows the approximate age of the individual at the end of each period :—

Detail.	Years.	Approx. Age on Completion.
At R.M.C., Duntroon	4	17-19 (Entry) to 21-23 (Leaving).
Administration Attachment to Unit	1	22-24.
University	2	24-26.
Regimental duty in Australia ..	1	25-27.
Attachment to R.E. or R.C.S. ..	1	26-28.
Total	9	

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HISTORY OF THE 12th COMPANY, ROYAL ENGINEERS.

(*Concluded.*)

By LIEUT. M. R. CALDWELL, R.E.

CHAPTER VI.

Louverval Sector (*See Map* 9).—The new sector was the quietest the Company had so far encountered during the War, the German lines were about 1000 yards distant, and there was little or no shelling. On the 23rd January Headquarters and one section moved to back billets, the other three remaining forward and carrying out routine trench work until February 10th. The 400th Field Company then took over this sector and the 12th Company side stepped and took over work on the Pronville Sector from the 105th Company, the transport moving to Favreuil.

The Company were now busily engaged in strengthening the line, building dug-outs, machine gun emplacements, etc., and preparing for the attack which was known to be coming soon. During March the work increased in intensity and was hurried on as fast as possible. Two of the most important jobs were the erection of a Brigade Battle Headquarters, consisting of fifteen elephant shelters let into the side of a sunken road and fitted up with tables and chairs, all of which was completed in four days and drew a warm letter of praise from the Brigadier, and, on the 12th March, the laying of two large minefields, each consisting of several hundred 60lb. Trench Mortar bombs, in No Man's Land as a protection against tanks. There was also, of course, the usual work of strengthening the defences and improving shelters and Aid Posts.

A detailed defence scheme had been prepared, and on March 9th a practise " stand to " was carried out at 5.30 a.m. by all the Divisional Troops, this being repeated on the 12th and 14th, so that all men knew their battle positions.

German Offensive Launched.—At 1.30 a.m. on March 21st all troops were ordered to " stand to " in their battle positions at 5.30 a.m., as the attack was expected that day.

At 5.0 a.m., just as the Sappers were forming up on the road outside their quarters, a terrific bombardment opened, and guns of every calibre plastered the sector with gas and high explosive from the Corps Line to the Front. One shell struck the officers' Mess, where were Major Williamson and C.S.M. Rouse, killing them both. In spite of this loss, however, the Section Officers (Lieuts. Noble, Veitch and Newcombe) rallied their men, and, in the semi-darkness, made worse by the wearing of gas masks, led them, without further serious casualties, to their positions in the Corps Line.

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Of the attached Infantry, the Durham Light Infantry were at the horse lines and took no part in the day's fighting; the West Yorkshire detachment, under their officer, took a wrong turn and were not seen again, but the Essex Regiment party, under a Sergeant, reached their allotted positions and behaved with the greatest gallantry throughout the fighting.

The bombardment continued with unabated fury for five hours, but luckily the Company was well extended and was able to avoid serious casualties. Several casualties had occurred at the horse lines, and teams were sent forward to remove Tool Carts, etc., from the forward billets. On Captain Langley leaving to take command of the Company, the transport was put under the orders of Lieut. Hudson of the 459th Field Company.

At midday there a lull in the shelling of the Corps Line, which enabled the Company to be reorganized. The situation at this time was as follows:—The 18th Brigade was still holding on to its positions in the Reserve Line, but the right flank was gone, and on the left the 71st Brigade was holding a defensive flank thrown back from the Reserve Line to the Corps Line at the old Company billets. The 12th Company were in the Corps Line in front of Morchies with a company of the 11th Battalion Leicestershire Regiment, on their left and 11th Essex on their right. The Company was organized in section posts, each with four or five fire bays, there being two sentries per section. The 11th Essex attached infantry were used to keep touch with their own battalion on the right, and to bring up ammunition from behind Morchies. In this latter work they behaved most gallantly, twice moving up through the shell-swept village. The sergeant was subsequently awarded the D.C.M.

Heavy Losses.—At 1.0 p.m. the bombardment reopened and increased in intensity till 3.0 p.m., continuing with terrific violence till five o'clock and then gradually dying down until by 6.30 p.m. there was comparative quiet. During this period the Company suffered heavily as there were gun pits in front and Morchies village behind their section of trench, and, owing to the arrival of reinforcements on the flanks, they were unable to extend outwards as had been done in the morning.

Situation at 4.0 p.m.—Meanwhile the situation had become most critical. The 18th Brigade, although still holding its positions, was being gradually surrounded, and by 4.0 p.m. the enemy was established on the Lagnicourt Ridge and was threatening the Corps Line near the Beugny-Lagnicourt road. On the right also the Germans were advancing on the Corps Line through the 51st Division trenches.

At dusk a mist came down and a retirement to the Corps Line was ordered, the last troops reaching the trench at 7.25 p.m. The enemy followed up rapidly, and a few moments later his patrols appeared

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on the far side of the wire. The Sappers, who at last saw a chance of "getting some of their own back," opened rapid fire and quickly drove them off. Our men then went out and closed the gaps in the wire left for the retreating troops.

At 11.0 p.m. the Line was reorganised, and the Company, together with Sections of the 459th and 509th Field Cos., were withdrawn to a position along the Vaulx-Beugny Road.

March 22nd.—A comparatively quiet night was spent, but at 5.0 a.m. the men were moving again. It was now decided to strengthen the position between Morchies and the Army Line, and accordingly a strong point was laid out, commanding the valleys up from Bois de Vaulx and Maricourt Wood, with a good field of fire. Work was begun at 6.0 a.m., tools and wire having been collected from Beugny, and after a few hours an effective rallying point for 200 men had been constructed.

By about 10.0 a.m. the enemy had broken through the Corps Line and was forcing his way into Vaulx. Orders were then received to form a defensive flank facing the village, and a line was taken up about a mile to the North of Beugny, astride the Vaulx road.

The attack continued throughout the morning, and at 2.0 p.m. all the troops west of the Beugny-Lagnicourt Road began to retire. In view of this situation the Company wheeled round to face the retreating infantry, who were very disorganized with few officers and little ammunition.

12th Company hold the enemy's attack.—With some difficulty, however, the officers of the Company rallied them, and they began once more to advance. An extended line was now taken up some 300 yards behind the Vaulx-Morchies Road, with the left flank back, to connect with the troops retiring from Vaulx, and the right flank on the strong point built earlier in the day.

During the afternoon the enemy brought up field guns to the high ground north east of Vaulx and began shelling the position over open sights at 2000 yards' range. Their Infantry continued to advance up the Vaulx valley, and the troops on either flank of the Company fell back once more. In spite of its isolation, the Company, together with about 60 Infantry under the command of the Sapper Officers, still remained in this position facing north east. Heavy fire was directed against large bodies of the enemy advancing up the valley south east of Vaulx, and all attempts to cross the Vaulx-Morchies Road were frustrated, thus preventing the Germans from pushing on to Beugny and so cutting off the 18th and 71st Brigades who were fighting behind Morchies.

The fighting continued during the afternoon and evening, and although the Company had been isolated since four o'clock and had been attacked not only by enemy infantry and artillery but also by low flying aeroplanes, the men never wavered, but continued

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fighting steadily till 6.30 p.m., by which time there was a great lack of ammunition. The situation was also serious. On the left the Army line was being attacked over a mile in rear, and on the right Morchies had been taken and the line was being pushed back behind the Bapaume-Cambrai Road. The Company was therefore withdrawn to the Army Line, where they dug in with 25th Division troops on either flank, remaining there till midnight, when they were withdrawn.

Losses.—During the two days' fighting the 12th Company had suffered heavily, for, out of an effective strength in the line of 5 officers and about 100 other ranks, the casualties had been 2 officers and 13 other ranks killed, 30 other ranks wounded and 7 missing. The attached Infantry casualties were 1 officer and 12 other ranks missing and 6 other ranks wounded. Two Tool Carts and the Technical Wagon had also been lost.

Honours Awarded.—The Company was subsequently specially mentioned in both Brigade and Divisional Reports for the part they had played in the fighting of these two days. Individual acts of gallantry are difficult to pick out. On the 21st Sergeant Fern (who was wounded), and Corporal Bryden of Headquarters, had remained under heavy fire with four wounded men and the Company stores. As the enemy began to approach, Sergeant Fern sent Corporal Bryden back with the secret papers, and, after evacuating the wounded men, retired himself saving what he could. Sergeant Fern was awarded the Distinguished Conduct Medal and Corporal Bryden the Military Medal. Also for their conduct during the operations Captain Langley was awarded a Bar to his Military Cross and Lieut. Veitch the Military Cross. In all, about eight Military Medals were won, while several other men were mentioned in Despatches.

After being withdrawn on the night of the 22nd-23rd the Company marched across country to Biefvillers and thence to Achiet Le Grand where they arrived at 6.0 a.m., and were allotted quarters in Buchanan Camp, all being footsore and dead beat after the nine mile march on the top of the heavy fighting of the last two days. At 9.0 a.m., however, they were roused once more to 'stand to,' though nothing further happened.

Move to the North.—On March 24th the Company marched to Puisieux and entrained, arriving at Mondicourt the next day, afterwards moving on to Peselhoek where they arrived on the 26th, and marched again the same day into camp at Elverdinghe.

The next day they marched to St. Jan ter Biezen and on the 28th to Eeke, south of Steenvoorde. The company at once set about reorganising and re-equipping, no light task after the losses they had sustained, for not only had two complete Tool Carts and the Technical Wagon been lost, but also nearly all the stores and the men's kits. After some days, however, many of the casualties had been replaced and things were once more becoming 'ship shape.'

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On March 29th H.M. the King visited Steenvoorde to congratulate the 6th Division on its work in the recent retreat, and on the 30th General Sir Herbert Plumer, commanding the Second Army, visited the Company and congratulated the men in glowing terms on the part they had played.

The Salient Once More.— On April 3rd the Company moved into the Ypres Salient once more, marching from Ypres to 'Sapper Camp' near Potijze, the scene of their labours in 1915 and 1916. The work on which they were employed was chiefly in the Reserve Line, and besides the old mud and drainage problem, the work consisted almost entirely of the erection of reinforced concrete pillboxes and shelters.

On the 10th the enemy attacked to the south of the Divisional front and caused a retirement, the 6th Division having to fall back to conform with the new line. The Company was, therefore, employed on the preparation first of this line, and then of a new line from Zillebeke Lake to the point where the Messines Road crosses the Canal south of Ypres, which was dug and wired with a complete line of reserve strong points. Other important work was the preparation for demolition of bridges, dug-outs, water supply and roads in case of retreat. These preparations were carried out all over the area south east and south of Ypres.

On April 16th, the Divisional front having been changed, Company Headquarters and Nos. 1 and 2 Sections moved to a farm half a mile south of Vlamertinghe, No. 3 and 4 Sections moving to forward billets in the Ramparts near the Lille Gate. The line was now back to the 1916 defences, and even behind them in places, and the Ramparts once more became extremely unpleasant! On the 21st four other ranks were killed and five wounded by a bomb which fell at the forward billet.

During the middle and end of April constant attacks were carried out by the enemy and in consequence the Company had frequently to 'stand to.' Ypres and the neighbourhood were constantly having heavy concentrations of gas put down upon them, in consequence of which the gas proofing of dug-outs and cellars formed a large item in the work of the Company.

About this time the enemy captured Mt. Kemmel, and thus had complete observation of the country all round. The Sections at Headquarters, therefore, had at once to set about camouflaging roads and all work. Several miles of really substantial camouflage on hop poles 12 feet high were therefore erected on nearly all the roads in the neighbourhood.

Demolitions prepared.—On May 3rd the sluice gate of Zillebeke Lake was blown up in order to flood a large tract of country to the south, in anticipation of an enemy advance. At one spot, however, a light railway embankment diverted a considerable volume of water into the trenches occupied by an unfortunate infantry

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battalion. This battalion was, needless to say, avoided very carefully after this by the officer who had carried out the demolition !

The remainder of the month was a period of anxiety owing to another heavy German attack being expected. Work was therefore pushed on feverishly, and the forward area was strengthened with machine gun posts, strong points and wire, and the back areas with new lines of trenches and breastworks.

During April and May, owing to constant enemy attacks and demonstrations, the Company was frequently ordered to ' stand to,' although they were not again called upon to take an active part in the defence.

On June 9th the Company was relieved by the 11th (Field) Company (33rd Division) and marched back to rest billets near Poperinghe, where they remained training until the 25th. A comprehensive sports and training programme was organized, culminating in a sports competition, including driving and section drill, which was judged by the C.R.E. (Lieut. Col. H. A. L. Hall, M.C.), and which was won by No. 1 Section (Lieut. Vachell).

Dickebusch Sector.—On the 25th the Company moved up and took over the Dickebusch Sector from the 28/3 Compagnie du Génie (46th French Division). Company Headquarters and Nos. 1, 2 and 3 Sections went into Lanbouver Farm while No. 4 moved to forward billets north west of Dickebusch. The enemy here held a most commanding position in Ridge Wood, which necessitated practically all work, even on rear lines, being done at night. On July 14th, however, the 18th Brigade carried out an attack on Ridge Wood, which not only captured its objectives, but also established a superiority in moral over the enemy which was subsequently never lost.

The work in this sector chiefly consisted of the improvement of the defences by means of dug-outs, machine gun emplacements and the erection of pillboxes, many of which were of the ' Moir ' pattern, consisting of concrete blocks and steel roof. Several tunnelled machine gun emplacements were also constructed in the banks of Dickebusch Lake. A Reserve Line was also constructed, with the help of large infantry parties, just east of Zevecoten and Ouderdom, and a considerable amount of help was accorded the R.F.A. in work on their battery positions.

On July 5th Captain Langley left to take up the duties of Adjutant to the C.R.E., Lieut. Noble becoming second in command.

U.S.A. Engineers Trained.—One feature of the work in this sector was the training of two platoons of the 102nd American Engineers, who were attached to the Company from July 25th to August 18th, and with whom a very good liaison was established.

Move to Somme Area (*See Map* 10).—On August 21st, the 6th Division was relieved by the 27th American Division, D Company,

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1st Battalion 102nd U.S.A.E. taking over from the 12th Company, who withdrew to rest at Wizernes near St. Omer. Here they remained, carrying out training and musketry on the range at Lumbres, until the 29th when they moved to Moulle. On September 1st they marched to Arques and entrained, proceeding to Bonnay on the Ancre, where they remained carrying out further training from September 2nd to 11th. On the 11th they marched to Vaux sur Somme and the next day moved by bus to Tertry for further work in the line. Company Headquarters and two Sections were in Tertry, while two Sections were forward between Villevèque and Atilly. The front line at this time ran along the east side of the St. Quentin and Holnon woods.

On the night of 17th/18th September, Lieut. Veitch laid out a tape line as a ' jumping off point ' for the Divisional attack at dawn the next morning. The work was done under extremely heavy shell fire and in strong concentrations of gas, but was completed satisfactorily, and for his bravery Lieut. Veitch was awarded a bar to his Military Cross.

Unsuccessful attack.—The next day Nos. 3 and 4 Sections were with the R.F.A., in order to clear tracks and construct bridges, Nos. 1 and 2 being kept in Reserve, as it was intended that they should move forward for consolidation after the attack. The attack however, was a failure, only very little progress being made. During the next two days the 18th Brigade launched further attacks in which the Company participated, consolidating captured ground and making reconnaissances of wells and dug-outs. Holnon village was eventually captured on the 20th.

During the next week the Division carried out further attacks on the high ground north east of Holnon, eventually making good the ground on the 26th. The 12th Company again took part, helping to consolidate the ground won.

On the 29th the Division was relieved by the 47th French Division, and the Company moved back to Tertry where they remained for four days resting and training.

On October 4th the Division moved into the line once more, the Company going into bivouac in fields west of Bellenglise, and working for two days on repairs to cellars and captured dug-outs for use as Divisional Headquarters. On the 6th, Company Headquarter moved to Magny la Fosse and two Sections forward into gun pits near Presselles Farm.

Further Attacks.—The next night forming up lines were taped out for the Divisional attack on the morning of the 8th, with which parties went forward to consolidate, repair roads and wells, and reconnoitre. This was repeated for another attack on the morning of the 9th. This attack captured Bohain, a small town in which civilians were found for the first time during the advance. The

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12th Company parties were about the first troops in the town, and in consequence were given an extraordinarily cordial welcome by the inhabitants.

Craters and Mines.—The streets in Bohain had been heavily mined, about a dozen large craters having been blown. Many cellars also had delay action mines in them, calling for very skilled and careful work in their detection and removal.

On the evening of the 9th the Company moved forward to Montbrehain, and early on the 11th moved up to Bohain and immediately began work on the craters in the roadways. Fortunately there was a large dump of German engineer stores at Bohain which helped the reconstruction a great deal, for there were no infantry parties available, and the Company worked almost continuously for several days before the work was completed. Reconnaissances and repair of roads east of Bohain were also carried out.

On the night of October 16th the Company taped out forming-up lines for the 18th Brigade attack next morning, with which repair and reconnaissance parties were sent forward.

On the 19th a lot of repair work on the wells and roads in and to the east of Vaux Andigny was carried out, and the next day the Company moved up to St. Souplet. During the next two days repairs and reconnaissances were carried out in the area east of the River Selle.

On the night of the 22nd/23rd Lieut. Horne laid out tape lines for an attack which was to take place the next morning. The work was carried out under an extremely violent enemy bombardment with high explosive and gas shell. Lieut. Horne was wounded early, but, after having his wound dressed, he returned and completed the work, which was of the greatest importance as the attack was to be delivered in the dark. That the attack was entirely successful must in a large measure be attributed to Lieut. Horne's courage and devotion to duty. He subsequently received the Military Cross.

The attack was again followed up by reconnaissance and repair parties. On this day Lieut. Vachell carried out some very daring and gallant reconnaissance work in an area which was being heavily bombarded. For this he received a bar to his Military Cross.

This attack was followed by another on the 24th, which brought the Division up to the bank of the Sambre-Oise canal. Attention was then turned to the repair of the metre gauge railway from Catillon to Basuel, and further road repairs. After this, until the end of the month, a considerable portion of the Company was engaged in constructing floating foot-bridges for an attack on the Sambre-Oise canal early in November. Although this attack was not carried out by the Division, the footbridges were used by the 218th Field Company for the 32nd Division's attack.

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On October 30th the Officer's Mess was hit by a shell, and 2nd Lieut. Hanstock, who had only just joined the Company, died of the wounds he received.

On the 31st the Company were relieved by the 218th Company, and marched back in the early morning to rest billets at Fresnoy le Grand. Here they remained for five days, training and making targets for the use of the 18th and 71st Brigades.

On November 5th the Company moved to Busigny and on the 7th to Catillon, carrying out work on bridges over the canal, and repairs to roads and wells, and moving forward again on the 10th to Autreppes near Cartignies.

Armistice declared.—Early the next morning a message was received stating that an Armistice had been declared and that hostilities would cease at 11 o'clock that day, thus bringing 4¼ years of fighting to a close.

Repair Work on Roads.—On the 12th the Company moved forward to Avesnes where further repairs to roads, and the filling in and bridging of craters was carried out until the 14th, when they went on to Felleries. While here, two important and difficult pieces of work were carried out. North east of Felleries the railway crosses the road to Solre le Chateau by means of a heavy plate girder bridge of about 36 foot span. The Germans had fired charges at one end, dropping that end into the road, which was thereby blocked. The 12th Company was ordered to clear the road for traffic.

It was found that there were no jacks or other stores available for raising the fallen end on to a trestle, and it was not desirable to cut the bridge up by means of explosives. The only alternative, therefore, was to haul it up into a vertical position standing on one end at the side of the road, thereby leaving all but 6 feet of the road clear. This operation took a considerable amount of care and forethought, for only the light tackles of the 12th and one other Field Company were available. It was, however, accomplished successfully and the bridge secured in position.

The other work done was the repair of the road and the culvert about 1½ miles east of Felleries. The road, which is here on an embankment about 20 feet high, crosses the Felleries rivulet by a brick culvert. This had been mined, though only the charge on one side of the road had gone, the remainder of the culvert being blocked as a result of the explosion, thus damming the stream, which had formed a lake 15 to 16 feet deep and several acres in extent. It was necessary to let this water escape slowly down the valley, or enormous damage would have been done. A shaft was therefore sunk through the side of the crater down to the undamaged part of the culvert and was carefully lined with mine cases, and down this the water was allowed to escape slowly. When it was all drained off a new culvert was put in, the embankment being reinforced with

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large tree trunks, above which the roadway was filled in and well metalled. The Company gained considerable praise from the Chief Engineer, Fourth Army, for this work.

This completed a period of extremely hard and trying work during the recent advance. Much of this work had been of a most dull and monotonous character, and had often been carried out under heavy fire. Four or five hours' work would invariably be done either before or on the top of a day's march, and rest and sleep were somewhat elusive quantities, often being conspicuous by their absence. All ranks, however, had worked willingly and uncomplainingly, and their efforts had at last been crowned by Victory.

March to the Rhine.—On November 20th the March to the Rhine began with a move to Solre St. Gery (13½ miles), moving again on the 22nd to Erpion (6 miles), and on the 24th to St. Aubin (13½ miles). Here they remained, carrying out training until the 30th, and were inspected by the G.O.C. 6th Division (Major General T.O. Marden, C.B., C.M.G.) on the 29th.

The remainder of the march is best given in the form of a table, as follows :—

December				Miles.
1st	St. Aubin	to	Ermiton sur Biert ..	8
4th	Ermiton sur Biert	,,	Evrehailles	13½
5th	Evrehailles	,,	Chateau de Fontaine ..	13
6th	Chateau de Fontaine	,,	Havelange	7
8th	Havelange	,,	Terwagne	7½
9th	Terwagne	,,	Comblain la Tour ..	13½
11th	Comblain la Tour	,,	Lorce	9
12th	Lorce	,,	Stavelot	13
13th	Stavelot	,,	Weismes (Germany) ..	10
14th	Weismes	,,	Elsenborn Barracks ..	7
19th	Elsenborn	,,	Montjoie	8½
20th	Montjoie	,,	Olef	16½
21st	Olef	,,	Roggendorf	9
22nd	Roggendorf	,,	Elsig	9
23rd	Elsig	,,	Erp	12

The march to the Rhine was now completed and the 6th Division settled down for the first time for five years to a Christmas under peace conditions.

For the remainder of December and January, the Company carried out training in more or less the same manner as during rest periods in the War, doing a certain amount of drill, musketry, &c., as well as works on billets for the Division.

On January 2nd the Company moved to Borr and on the 4th one section was attached to the 16th Brigade at Kettenheim and another to the 18th at Lechenich. Extensive reconnaissances were also carried out by the officers to obtain information regarding roads,

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railway stations, bridges, waterways, electricity, water supply and factories in the occupied territory.

During February and March the chief work was on hutting, baths, incinerators and other billet and camp improvements, training and sports being also largely carried out.

On March 23rd the Company moved to Lechenich and on April 3rd marched back to Brühl, Lt. Kerr and a detachment remaining to hand over the work at Lechenich to the 93rd (Field) Company.

Divisions renamed.—With the departure of most Regular Units a reorganization of the Army of Occupation now took place, the old Divisions being broken up and new ones formed.

On April 5th the G.O.C. Midland Division (which had taken the place of the 6th) inspected the Company, and the C.R.E. of the 6th Division (Lieut. Col. H.A L. Hall, M.C.) made the Company a farewell speech.

Demobilization was now proceeding very fast, and during the early part of April large numbers of officers and men were sent Home or to other units for demobilization, and on April 18th the Company was reported as down to Cadre 'A.' There were now no officers and very few men left who had known the Company for more than a few weeks.

During the remainder of April and most of May the Company was chiefly occupied in sorting and checking equipment, cleaning up, and a few minor barrack works.

Return Home.—At last the Company was ordered Home, and on May 23rd the Cadre entrained at Brühl station. They arrived at Antwerp the next day and proceeded to the embarkation camp, where they remained four days.

On the 29th the Company, together with the Cadres of many other Regular Units, embarked, the personnel on the S.S. Arbroath and the transport on the S.S. Huntsclyde. Both vessels arrived at Tilbury the next day, when the Company disembarked, having been on Active Service for four years and nine months. Of the Cadre who disembarked, there was no officer or man who had left England with the Company in 1914.

CHAPTER VII.

Ireland.—The Advance Party left for Ireland on May 30th, while the remainder went into camp at Purfleet for a few days, after which they proceeded to their pre-war Command, arriving at Limerick on June 12th. Here they were allotted quarters in Ordnance Barracks, the old Artillery barracks, in which were already the 415th Lowland Field Company T.F. The Cadre was then amalgamated with this Company, the whole becoming the new 12th (Field) Company.

Demobilization was still going on apace, and it was not long before practically all the men who had been with the Cadre or the Territorial

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Company had left, and had been replaced by men on normal regular engagements, the majority of whom were recruits.

Irish Rebellion.—There was not much chance, however, for the Company to arrive at any complete state of organization, for very shortly the Irish Rebellion broke out afresh, Limerick being a particularly hot Republican centre.

The Company now found itself scattered in small detachments, varying from two to fifteen men, over an area comprising the whole of Cos. Clare and Limerick, as well as more than half Kerry and Tipperary. The work on which they were engaged consisted of hutting, defences of billets and Police barracks, as well as minor routine works on barracks, etc. Many reprisals were also carried out. These usually took the form of demolishing houses of leading Sinn Feiners in the neighbourhoods in which outrages occurred.

Owing to more than half the Company being always on detachment, and also to the unsettled state of the country, it was impossible, during the two and a half years that the Company was in Limerick, to carry out any combined work in the way of either training or sport, both of which consequently suffered heavily.

On many occasions officers and men came into violent contact with the Rebels. On one occasion, on June 6th, 1920, while on his motor bicycle on his way to Castle Fogerty, 2nd Lieut. R. R. Gillespie was held up and attacked by some twelve Sinn Feiners. He at once drew his revolver and replied to their fire, and, in spite of being slightly wounded, succeeded in wounding two or three of his assailants and putting them all precipitately to flight. He was then attacked by two more men from behind, one of whom succeeded in hitting him in the thigh, but they also bolted when he fired his last two rounds at them. Lieut. Gillespie then rode off, but was knocked off his motor bicycle by some cattle as he was unable to apply the brake owing to his wound.

He then walked a mile and a half to obtain a conveyance, passing several parties of Sinn Feiners on the way, all of whom allowed him to pass unmolested although he had only an unloaded revolver in his hand.

The following is an extract from 6th Division Orders dated 10th June, 1920:—

294 *Congratulatory Order.*

Please convey the congratulations of the G.O.C. in C. to Lieut. Gillespie, Royal Engineers, on his gallant conduct at Drombane.

The Divisional Commander wishes to express his great admiration of the gallant conduct of Lieut. Gillespie, Royal Engineers, in fighting and routing a body of armed men when

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he himself was wounded, and wishes to convey his hearty congratulations on his act and escape. This is a brilliant example of what initiative, presence of mind and gallantry can do.

Ordnance Barracks were shared from time to time with various other units, chief among which were the 43rd Oxfordshire Light Infantry.

In July, 1921, the so called "Truce" was declared, and, in the south, active operations on both sides having ceased almost entirely, things became considerably quieter.

Evacuation of Southern Ireland.—During January, 1922, rumours about the movement of units to England began to spread rapidly, and it was not long before rumour materialized into fact, and orders were received.

Move to Aldershot.—Preparations for the move of the Company were begun at once and the Advance Party left for Aldershot on February 11th. The Company still remained split up, however, until late in February, when the detachments came into Limerick on the evacuation of the various stations.

On the morning of February 28th, the Company, under the command of Captain A. J. Cruickshank, D.S.O., finally left Limerick, and sailing from Waterford to Fishguard, arrived at Aldershot, with the 38th Company, on March 1st.

Here, after nearly three years, the whole Company found themselves together once more, and having been allotted, with the 23rd and 26th Companies, to the 1st Division, were able to reorganize and carry out the normal annual training for the first time since the War.

During the Fieldworks course, the Company were selected to carry out experiments with a new type of Heavy Pontoon Bridge with steel superstructure, and with the Martel Box Girder Bridge.

Chanak.—The 12th Company were not to remain in peace long, however, for, on September 18th, owing to the increasing probability of trouble in the Near East and the necessity for increasing the garrison at Constantinople, orders were suddenly received to prepare for service overseas, at war strength in officers and peace strength in other ranks. The work all went smoothly, and on September 22nd the Company, under the command of Major A. H. Bell, D.S.O., O.B.E., with Captain K. B. S. Crawford and Lieuts. H. B. Foy, S.StD. Skinner, S. R. C. Shaw and P. G. Wavish, and C.S.M. R. P. W. White, D.C.M., as the Sergeant Major, entrained at Aldershot and proceeded to Glasgow, where they embarked with the 2nd Battalion Grenadier Guards on H.T. "Empress of India," on the 23rd, sailing for Chanak the same day.

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The dispatch with which the units, who had been suddenly warned for service, got ready, was mentioned in the following Aldershot Command Order, dated 23rd September, 1922 :—

1242 *Despatch of Drafts (Appreciation).*

The General Officer Commanding in Chief wishes to record his appreciation of the energy, good organization and keenness displayed by the Units, Services, Corps and Departments (particularly the R.A.O.C.) concerned in the rapid preparation and despatch of units and drafts overseas from the Command.

He wishes especially to bring to the notice of all ranks the two instances below, which are typical of the fine soldierly spirit and readiness in emergency which has ever been an asset of the British Army :—

2nd Battalion Grenadier Guards.

12th Field Company, Royal Engineers.

1st Infantry Brigade Signal Section (from 1st Divisional Signals).

September 18th (Monday).

20.30—Received orders to prepare for immediate service overseas. Drafts to complete to be prepared for.

September 21st (Thursday).

18.55—All vehicles, baggage, stores, ammunition loaded on train.

September 22nd (Friday).

21.25—Main bodies entrained.

❁ ❁ ❁ ❁ ❁ ❁

The transport arrived at Chanak on October 2nd, and the Company disembarked at Aeroplane Pier and unloaded stores that evening, arriving in camp very tired at 6.0 a.m. on the 3rd.

The Company now formed part of the 28th Division which was in this area, and which was commanded by Major General T. Marden, C.B., C.M.G., Lieut.-Colonel C. B. O. Symons, C.M.G., D.S.O., being the C.R.E.

The Company was at first under canvas just north of the town, but as winter approached they were moved into rather indifferent billets in the same area.

No horses had been brought with the Company from England, but shortly after its arrival 49 draught horses, mules and riders were issued.

The 12th Company took over works from two Sections of the 55th (Field) Company, who returned to their Headquarters in Constantinople.

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Three days after arriving, No. 3 Section (Lieut. Foy) moved on detachment to Tekke, about two miles north of Chanak. They did not rejoin Headquarters until January 3rd, 1923.

On November 4th, No. 1 Section (Lieut. Skinner), was sent to Soghanli Dere on the Gallipoli Peninsula, where a battery of 8" Howitzers was encamped, to put up Nissen huts and other buildings. No. 2 Section (Lieut. Wavish), joined it on January 3rd, 1923, returning to Chanak on February 23rd, while No. 1 remained on until March 29th. In addition to hutting, this detachment started a masonry and pile pier near Soghanli, intended for the evacuation of heavy guns and ammunition. This work was eventually finished by the 24th Company.

The Military situation at this time was peculiar. A hastily entrenched line had been taken up about a mile from Chanak on the south and east and extending to the sea shore about three miles to the north. The trenches had been dug and wired by infantry and sailors, and wire was being added every day. The Turkish picquets were, in some places, only a few yards from ours, so that sentries were within speaking distance and in full view of one another.

During the winter the Company was chiefly employed on repair and maintenance of water supply, piers and roads, work on billets, such as erection of cookhouses, etc., erection of shelters near the front line and building retaining walls along the Nagara road (about $2\frac{1}{2}$ miles long), which road was also remetalled by an Armenian contractor under R.E. supervision. Electric light and hot water apparatus were also installed.

The next spring, the troops were again all moved out under canvas to avoid the Sandfly Fever which had previously been prevalent. This entailed considerable work on water supply by the Field Company, which included not only the upkeep of the old supply system, but also the erection of three new pumping stations, in which Merryweather pumps were installed, and the laying of a large amount of 4" steel piping.

The various piers in and around Chanak were a fruitful source of trouble, the timber being quickly demolished by some marine insect, greatly assisted by the bad seamanship of the Greeks. This entailed a very large amount of piledriving.

A rifle range of 20 targets was constructed at Nagara for the infantry, and another for the artillery south of the Koja Chai.

A large amount of work was also expended on the repair of Jibidelik Farm.

In all these works the Company was assisted by local labour, both skilled and unskilled, consisting of Russian refugees, Armenians, Greeks and the Black Sea Labour Corps, all of whom did useful work.

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On March 17th Major Bell became C.R. E. as well as O.C. Company, and on July 24th Captain Crawford took over the duties of Adjutant in addition to his own.

The Peace with Turkey was eventually signed on July 23rd, and orders for the evacuation were not long in being issued.

On August 18th Lieut.-General Sir C. H. Harington visited Chanak, and after inspecting the Camps, thanked the men for their good work.

All the 4" steel pipes had to be returned to England, but the remainder of the stores were purchased by the Turks. The piping was therefore taken up as soon as the camps were vacated.

On September 13th the Company moved to a camp near Aeroplane Pier, preparatory to embarking on the 18th on the transport "Hecuba." A few days before, the following message had been received from Colonel A. S. Cotton, C.M.G., C.B.E., D.S.O., who had taken General Marden's place as Divisional Commander :—

> "In bidding goodbye and Godspeed to the 12th (Field) Company Royal Engineers on the break up of the 28th Division, Colonel Commandant A. S. Cotton desires to place on record his appreciation of the good work cheerfully and invariably performed by the Company frequently under very trying conditions.
>
> He wishes Major A. H. Bell, the officers, W.O.'s, N.C.O's, and men the very best of luck, and hopes that it may be his good fortune to have this fine unit at some future time again under his command."

Return Home.—On the day of embarkation the following telegram was received from Lieut.-General Sir C. H. Harington :—

> "Thank you and all ranks of your Unit for all you have done and wishing you every success. I am very proud to have had your Unit under my Command."

The voyage was a particularly good one. The "Hecuba" anchored in Southampton Water on September 30th, and the Company disembarked the next day, and arrived at Aldershot about 1.0 p.m. on October 1st, proceeding to Gibraltar Barracks. Most of the men then proceeded on a month's leave.

The Company now rejoined the 1st Division, after almost exactly a year's absence.

The year 1923 closed with the usual Christmas Festivities.

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THE EXPERIMENTAL PONTOON EQUIPMENT.

Contributed by the R.E. BOARD.

INTRODUCTION.

Now that the new equipment has nearly reached the stage of production, it is thought that a history of the various stages of its development and the investigations that have led up to the final designs may be of interest.

The length of time required to carry out the necessary experiments and trials to evolve a new equipment will be realised from the following notes.

Certain information has already been published in the *R.E. Journal*, but it is thought that a complete *resumé* of the position would be more useful, and this paper embodies much of the previous articles (October, 1920, and September, 1921).

DEVELOPMENT AFTER 1918.

At the date of the Armistice the pontoon equipment was essentially the same as in 1914—a slightly improved pontoon of the same dimensions as before, some experiments in chesses and a design of wagon modified to withstand mechanical traction being the sole alterations.

To carry any transport heavier than a 2-ton axle load there were available: (*a*) a method worked out at the S.M.E. in 1914—embodied in an addendum to *M.M.E.*, but not re-published in the 1920 editions, and (*b*) the "Sankey" method, described in *M.E.*, Vol. III, p. 62.

It was clear that it would be necessary sooner or later to face the problem of an improved equipment capable of dealing with all loads up to the tanks.

At the date of the Armistice it must be remembered that the latter implied a monster of 35 tons, which rendered the problem a far greater one than it is at the present moment, when the tendency is greatly to reduce the weight of the fighting tank.

With this in view the first experimental work undertaken was to ask Professor Inglis to design a continuous steel girder, suitable for erection upon a "medium" bridge of normal pontoon equipment. Such a bridge was constructed and tried at Christchurch (described in *R.E. Journal*, October, 1920); it possessed certain mechanical defects which rendered it unsuitable in its original form.

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Since, however, in the interval between the date of ordering the bridge and that of its erection it had become clear that the then existing pontoon would have to be replaced by one of greater buoyancy, the further development of this bridge was abandoned.

In July, 1920, a proposal was made to provide greater buoyancy with our existing pontoons by decking the service pontoons and strengthening the couplings, thus providing sufficient buoyancy to admit of bays of 21-ft., using 9-in. x 4-in. steel joists.

Several pontoons were accordingly decked and much attention was devoted to various methods of strengthening the couplings. Piers of these pontoons were tested for " medium " and " heavy " loads, and were found to stand up to their duty in this respect.

A bipartite pontoon was submitted to a crushing test of 100 per cent. overload without damage, and the special strengthened couplings were tested to a breaking load of about 20 tons, giving a factor of safety of 2½.

Meantime, it was obvious that the Weldon trestle was not equal to the increased load, and a steel trestle was designed, constructed, and first tried in September, 1920.

This trestle as originally designed weighed 1,645 lbs. It was considered advisable to reduce this weight, and between October, 1921, and August, 1922, various suggestions and experiments were made. Two screw jacks were substituted for the Morris blocks, the legs were reduced to 14-ft. from 16-ft., and a special bracket was designed to give the 10-ft. variation required in height of roadway. Finally, in 1923, a nickel chrome steel transom was used, involving complete re-design of this member, with a consequent reduction in weight of 150-lbs.

The weight of the improved steel trestle is 1,200 lbs. as compared with 1,000-lbs. for the Weldon trestle; the steel trestle, however, will take an 8-ton axle load, whereas the Weldon trestle will only take a light load, *i.e.*, up to a 2-ton axle. (See Plate 1, Fig. II).

The decked-in pontoons and steel trestles went to Aldershot for trial in August, 1922.

A report was made in December, 1922, which, while holding that " any attempt to reconstruct the service pontoon equipment into such a form as to make it suitable for all grades of vehicles, must result in an equipment at once most unsuitable for quick work and light traffic, and difficult to assemble for heavy loads," went on to recommend concentration upon three bridges only, viz. :—

(*a*) Infantry Assault Bridge,

(*b*) Lorry Bridge,

(*c*) Bridges for 12 to 20-ton loads,

particularly emphasising that the normal Divisional bridge should carry lorries, and, if possible, " Infantry " tanks.

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Detailed criticisms on the equipment indicated objection to decking (as adding weight, difficulty in rowing, and in keeping clear of water), to the weight generally (especially of the joists, which were of mild steel 9-in. x 4-in. x 21-ft. and weighed 441-lbs.) and to the inconvenience of the couplings (particularly in loading and unloading wagons). Many detailed criticisms and suggestions were made which proved of much value in later designs.

The steel trestle was found to be generally satisfactory, subject to certain criticisms.

Experiments were proceeded with in order to work out "cut bays" for this bridge, but, owing to the developments now to be described, these were stopped.

Early in 1921 the question of stocks of pontoons and the problem of rapid production in war time came to the front. It was realised that the construction of wooden pontoons was slow, and the possibility of producing a metal pontoon was considered, in order to supplement production in an emergency.

It was hoped that a design made of pressed steel might be practicable, to facilitate rapid production once the very expensive dies were provided, but investigations showed that the thickness of metal necessary to give the pontoons adequate strength would render the weight excessive. Consequently it was decided to design a built-up pontoon of steel, and in the first place the following conditions were laid down :—

1. Limit of weight about 86-lbs. per foot run.
2. Buoyancy as for the experimental decked-in service pontoon.
3. To be unipartite, with bulkheads.
4. To be partially or fully decked with timber decking, and if fully decked, provision to be made for man-holes. No camber to be made in the decking.
5. Same facilities for coupling together as with the experimental decked-in service pontoon.
6. The "form" to be studied with a view to offering minimum resistance to the current—sides to be vertical (not "tumbled home" as in the German pontoon).
7. The possibility of carrying it on the existing wagons to be considered.
8. The pontoon for light bridge to be capable of being used for medium and heavy bridges.
9. Saddle loading to be adopted.
10. Ease and speed of construction of "Light" Bridge to be considered as a determining factor in the design.

By this time, however, it had become more and more obvious that efforts to make the best of existing pontoons by the means already referred to were not hopeful, and while the conversion of

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a number of these for trials was going on, the complete re-design of pontoon equipment was initiated.

The necessity for a bridge to carry 3-ton lorries had become more obvious; it had been found that a modified bridge using three sections of service pontoon per pier would not carry 3-ton lorries.

It was decided to concentrate on unipartite pontoons, and it was hoped that a 3-pontoon pier would carry lorries.

The investigations in connection with the proposed steel pontoon, though it has not proved entirely successful, have affected the subsequent design of the consuta wood pontoon finally adopted to such an extent that they will be given in some detail.

The design was limited, by the necessity of making use of the service wagon, to the following dimensions:—

Overall width 6-ft.; length 21-ft.; weight not to exceed 80-lbs. per man when carried.

The freeboard for a decked pontoon was agreed upon as 9-in. for normal load and 6-in. for heaviest load, and the loads foreshadowed were—on each pier—

For Light Bridge—	4½	ton.	max.— Amm. wagon and limber for 4.5 How. and team.
	3½	,,	normal—Infty. in fours in normal formation.
For Medium Bridge—	14½	,,	max.— (Foden Lorries continuous).
	10¼	,,	normal—(3-ton Lorries continuous).
For Heavy Bridge—	21	,,	max.— (medium D tanks).
	15	,,	normal—(8-in. How. drawn by 11-ton caterpillar).

Span to be determined.

The foregoing loads were based on an assumption of 15-ft. bays (wooden baulks) for light and 21-ft. (steel joists) for medium and heavy bridge.

Based upon these data several alternative schemes for the length and grouping of piers were worked out, involving bi-partite pontoons of two sizes—20-ft. and 10-ft.; 18-ft. and 6-ft.; 18-ft. and 27-ft.; and 18-ft. and 24-ft.; and also one with single 20-ft. pontoons only. All these proposals involved twinning the piers for both medium and heavy bridge.

Each of these proposals involved different dimensions for beam and depth.

After consideration of these proposals the idea of using two sizes of boats was rejected, as complicating equipment, especially not lending itself to transport upon a single type of vehicle.

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A 20-ft. boat, 2-ft. 11-in. deep and 5-ft. 6-in. maximum beam, with 5-ft. deck beam, was accepted as a basis for detailed design for all purposes, and to be calculated to weigh 75-lbs. per carrier, spaced 18-in. apart. One boat to suffice for light bridge; two coupled for medium; two pairs for heavy bridge. The boats to stand total immersion, with the weight placed on a 10-ft. saddle in the centre, without distortion, and similarly the maximum dead working load when standing on a sand bed without collapsing. It would not be expected to stand the latter test without some risk of damage.

The first design produced was actually 21-ft. long and gave a calculated buoyancy of 13,044-lbs. with 6-in. freeboard. The freeboards for the foreshadowed loads given above were calculated to be 11½ and 15½, 15 and 19¼, 8¼ and 14⅛-in., respectively, with a waterway of 9-ft. 6-in. in heavy bridge. It was calculated to weigh 2,000-lbs., *i.e.*, 77-lbs. per man with 26 carriers.

This boat was, in the first place, designed for gunwale loading. A second design was proposed with straight vertical sides and a central girder for saddle loading.

These alternatives raised the crucial question of the relative merits of gunwale versus saddle loading. Certain experiments were made, but were rather inconclusive, owing to the use of service pontoons and baulks not designed for gunwale loading. A decision, however, in favour of saddle loading was arrived at, on the grounds of greater rapidity of construction, shorter and lighter baulks in saddle loading, that gunwale loading involves each side of the pontoon being capable of carrying the maximum pier load in case of grounding, thereby involving extra weight, and of the complications involved at junctions between shore and floating bays and in securing the roadway over overlapping joists. Further, gunwale loading being of the nature of a continuous girder, presents indeterminate stresses. The merits of gunwale loading which are essentially greater simplicity of detail, facilities for adjusting length, variation in the number of roadbearers and interpolation of extra pontoons, were not considered sufficient to compensate for its disadvantages

The shape of the bow now required consideration, and an estimate was obtained from the National Physical Laboratory for experimental work on models in their tank. It was decided, however, that experiments should be made at Christchurch, with the assistance of the National Physical Laboratory, by towing various full-size shaped bows in the river, and it was agreed that such tests were more conclusive than those with models.

The shapes of bow tested were as shewn in Figs. 1 and 2.

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FIG. 1.

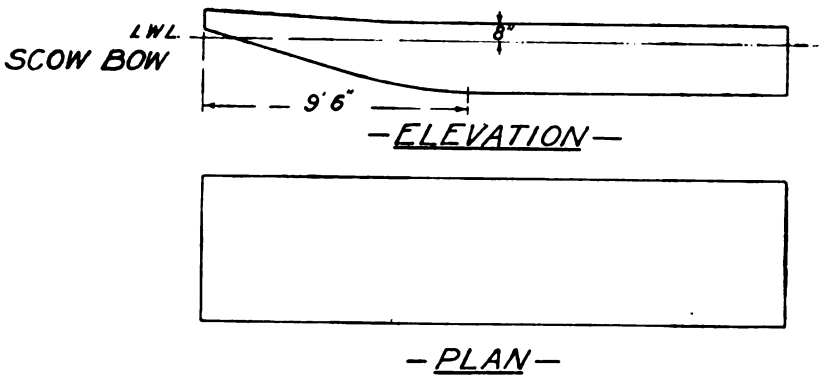
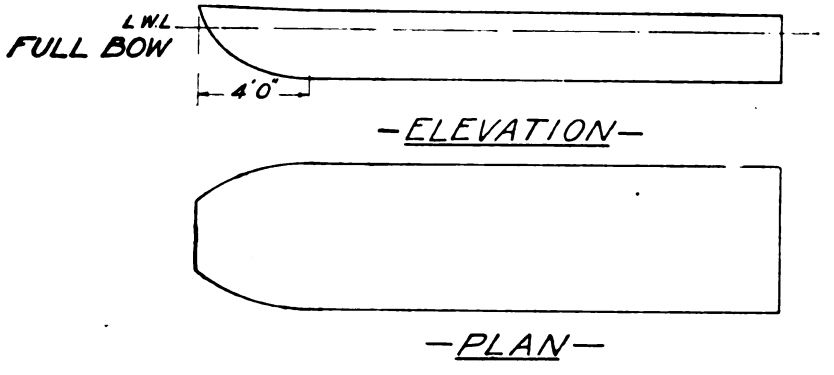


FIG. 2.



Two series of tests were carried out upon service pontoons provided with mock-up bow and stern. The first was under the direct observation of Mr. Baker, of the National Physical Laboratory, and the following is taken from the official report from the National Physical Laboratory :—

" In order to eliminate any effect due to velocity differences, the results have been put in the form of factors—

$$\frac{\text{resistance or pull in lbs.}}{(\text{velocity in miles per hr.})^2}$$

" For any limited range of speeds this factor for any form would not be seriously affected by small differences of speed, and may be considered as a criterion of resistance. The lower it comes, the better will the float be as regards anchor forces. This factor is shown in the last column of Table I, and shows the effect of difference of form fairly clearly.

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"The actual speeds through the water were probably somewhat in excess of the measured speed, as the tow was not sufficiently distant from the pinnace to be clear of some wash from the slip stream of the propeller. But this effect would be the same in all, and the figures can be used for purposes of comparison, and should err a little on the safe side for quantitative work."

"The general conclusions are as follows (See Figs. 1 and 2 and Table I) :—

(*a*) The parallel stern has a high resistance compared with the "full" stern (compare (1) with (3) and (6) with (7)).

(*b*) The scow bow is better than the full bow (compare (1) with (4) and (5) with (6)).

(*c*) Twin floats are not quite so resistful as two single floats (compare $\frac{R}{V^2}$ in (5) with 2 x $\frac{R}{V^2}$ of (3) and $\frac{R}{V^2}$ in (7) with 2 x $\frac{R}{V^2}$ of (4)).

(*d*) The "full" stern loses some of its advantages over the parallel stern when used in two floats, but is still definitely better. (The drop in $\frac{R}{V^2}$ passing from trial 7 to trial 6 is 1.8. The drop in $\frac{R}{V^2}$ passing from trial 1 to trial 3 is 2.0.) The latter is for a single float and the former for twins, and the result suggests that the advantage is gained from the outer corners of the stern only, the inner corners acting for all practical purposes as blunt ended or parallel sterns. The best combination is undoubtedly the scow bow with full stern, either as single or twin floats. It is understood that the scow bow is defective as regards buoyancy, requiring 4-ft. greater length than a "full" bow to give the same buoyancy. The trials showed that the scow had been cut away more than was really necessary, the fore end being about 9 or 10-in. above the water at 4.18 knots. It is understood that with a heavy bridge the floats will be loaded some 4-in. deeper, and the form can be filled out by dropping the scow bottom 3-in., keeping its slant about the same, and leaving a vertical fore end just clear in this deep condition in a fairly rapid stream. This would go a considerable way to eliminate the buoyancy defect and should not seriously affect the resistance."

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TABLE I.

Towing Tests of Bridge Pontoons. 7th and 8th July, 1921.

Pontoons towed on about 20-ft. rope behind 30-ft. motor-pinnace—

SINGLE FLOATS.

Trial.	Shape of Pontoon.	Speed m.p.h. V	Horizontal tow rope pull in lbs. R	$\frac{R}{V^2}$
(1)	Full bow and parallel stern	4.0	140	8.75
(2)		3.45	105	8.82
(3)	Full bow and full stern ..	4.31†	122	6.6
(4)	Scow bow and full stern ..	4.18	119	6.81

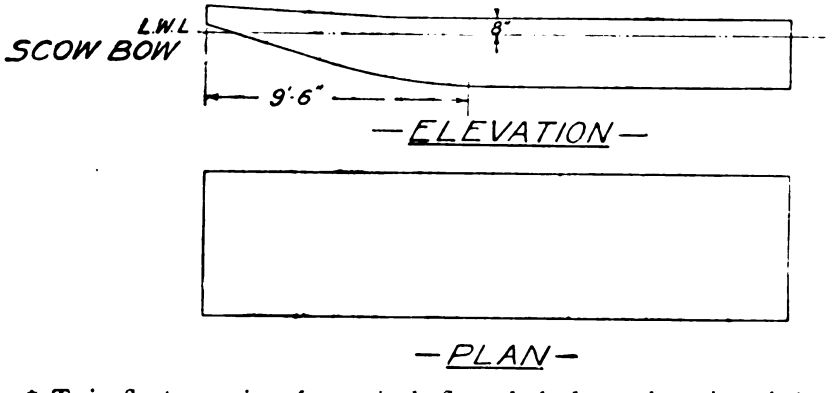
TWIN FLOATS.*

(5)	Full bow and full stern ..	3.47	154	12.8
(6)	Scow bow and full stern ..	3.73	142	10.2
(7)	Scow bow and parallel stern ..	3.67	161	12.0

Depth of water about 9-10ft.

The boats were in all cases loaded to 12-in. freeboard. The boats were towed behind a motor boat on a fixed and measured course in fairly slack water; one run up tide and one run with

FIG. 3.



* Twin floats consist of two single floats lashed together, there being only about two inches of water between them on their faying sides.

† Doubtful whether speed ought to be 5.18 giving $\frac{R}{V^2}$ 4.55

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FIG. 4.

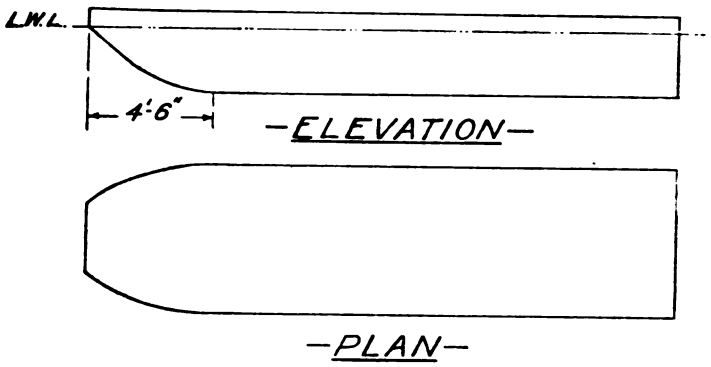
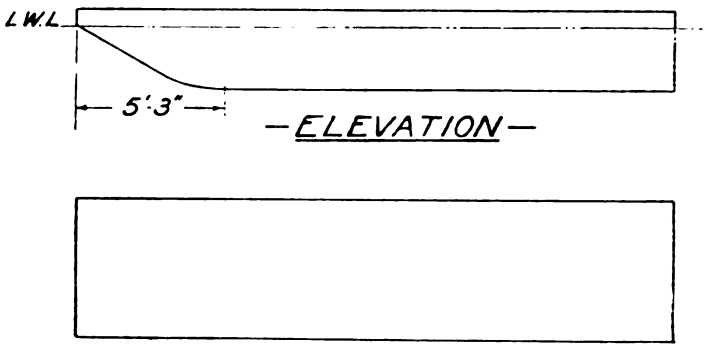


FIG. 5.



the tide were taken in each case, and the figures above are the average, so that the effect of the tide was neutralised.

The general conclusions from this report were (see Figs. 3, 4 and 5) :—

(1) The present full bow (equipment pontoon) is not good enough for speeds of current over 5 knots, as the bow waves would then be excessive and would swamp the boats.

(2) The present shape of bow is the best for use as a stern, as far as resistance to current is concerned.

(3) The scow bow (Fig. 3) is the best as far as resistance to current is concerned, but gives less buoyancy (63 per cent.). From observations of the waves, however, the scow portion could be lowered about 3-in. so as to bring the top of it to the load water line.

(4) It would appear that the best result would be obtained by striking a mean between the full type and the scow type bow, as in the design of the steel pontoon (Fig. 4) or as in an amended type, shown in Fig. 5. The difference between these two is that in Fig. 4 the bows

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are turned in in plan, whereas in Fig. 5 they are square in plan. Each type gives practically the same buoyancy (81½ per cent. and 79 per cent). Fig. 4 is better for the stern, but not quite so good for the bow as far as resistance is concerned. Fig. 5 is much easier to make.

As the stern for the light bridge must be square on account of coupling, favour was given to the bow of the new pontoon in Fig. 5.

(5) A prow bow does not appear necessary, but experiments at greater speeds should be carried out to test this.

A second series of tests was carried out in a choppy sea in Poole Harbour, with bows as in Fig. 4, in comparison with the service bow. In the case of the single pontoon the towing cable was weighted to bring the direction of pull as near as possible to that of an anchor rope.

The results of the tests were as follows (See Figs. 6 and 7) :—

FIG. 6.

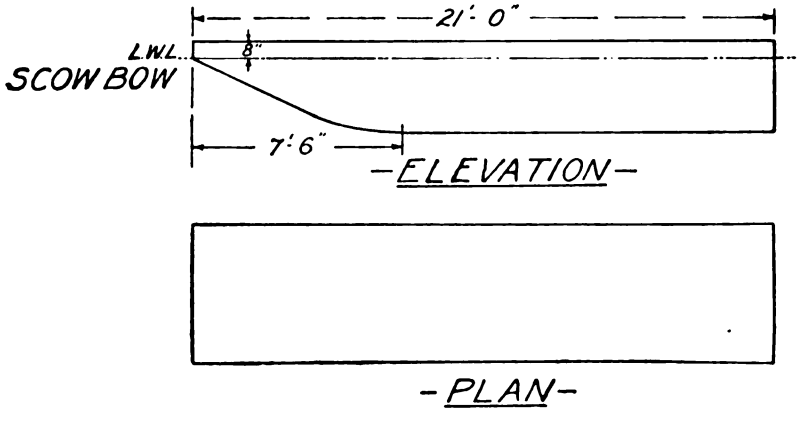
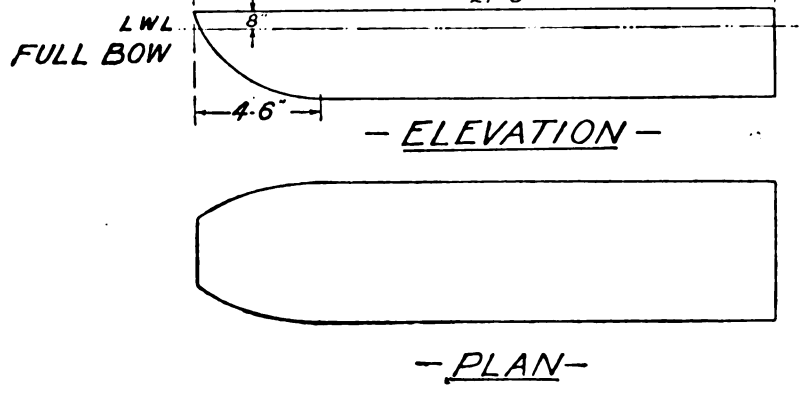


FIG. 7.



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Type.	Speed (V) m.p.h.	Anchor Strains (R)	$\frac{R}{V^2}$	Free-board.	Remarks.
Single boat. Scow bow and square stern ..	4.95	222	9.1	9″	The result of one up tide and one down tide run. On the run against the waves the boat swamped at a speed of 5.1 m.p.h.
Single boat. Full bow and square stern.	4.00	224	14.00	9″	Boat swamped on up tide run at speed of 4 m.p.h., equivalent to a speed of about 4½ m.p.h. in slack water.
Single boat. Scow bow and square stern.	7.85	728	11.8	16″	Stern waves practically up to the gunwales. On the down tide run the actual speed was 8.6 m.p.h.

From the above it will be seen that the scow bow as designed is considerably better than the full bow.

In order to test the relative merits of the scow bow and full bow as a stern for medium and heavy bridge, three sections were connected together and run as under :—

Scow bow, scow stern with one stern section between.	4.70	226	10.2	11″	Up tide at an actual speed of 5.12 m.p.h. The bow waves were up to the top of the gunwales, crest lopping inboard.
Scow bow, scow stern with one ordinary stern section between down tide trip only.	4.32	182	9.7	11″	
Scow bow. Full stern, with one stern section between (neglecting up tide a boat swamped early in run).	5.5	315	9.6	11″	Boat swamped on up tide trip at a speed equivalent to 6½ m.p.h. in slack water.

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The speeds and freeboard at which swamping took place are as under, the speed given is the relative speed of boat and water, allowing for the tide, and notes on the observed waves are added :—

Type.	Speed.	Free-board.	Waves.
Scow bow.	5.1	9″	Bow waves up to gunwales during run.
,, ,,	5.3	9″	Bow waves up to gunwales, swamping occurred after 200 yds.
,, ,,	4.3	11″	Waves 6″ below gunwales.
,, ,,	6.0	11″	Waves 3″ below gunwales.
,, ,,	4.1	9″	Waves 3″ below gunwales.
,, ,,	6.0	9″	Swamped after 100 yards run.
	7.1	16″	Waves 18″ below gunwales. Stern waves up to gunwales.
Scow bow.	8.6	16″	Stern waves up to gunwales.
Full bow.	4.1	9″	Bow waves up to gunwales.
,, ,,	4.8	9″	Swamped after 200 yards run.

Eliminating doubtful figures and taking the results broadly they can be indicated by a graph which shows the limit of swamping and the limit of safe loading for an *undecked* pontoon.

The following information can be obtained from such a graph for the new steel pontoon if undecked :—

	Safe in average water.	Swamp in.
Heavy Bridge Max. Loads.	4½ m.p.h.	5 m.p.h.
,, ,, Normal Loads.	5½ m.p.h.	6 m.p.h.
Unloaded.	Limit of allowable current.	
Light Bridge Max. Loads.	4¾ m.p.h.	5¾ m.p.h.
,, ,, Normal Loads.	6 m.p.h.	6½ m.p.h.
Unloaded.	Limit of allowable current.	
Medium Bridge Max. Loads.	6 m.p.h.	6½ m.p.h.
,, ,, Normal Loads. (3-ton lorries)	7¾ m.p.h.	8½ m.p.h.

As regards speeds of current up to which it is possible to use pontoons in bridges, a fresh consideration arises, namely, the pull which the current induces on the anchor.

Although a chain was put on the towing rope to sink it and to make it of about the same slope as the anchor cables in a pontoon bridge, the slope of the cable varied according to the pull, and it would have taken too long to adjust the weight to make the slope the same in all cases.

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In dealing with the strain on an anchor, however, allowance must be made for the above, and the measured pulls should be increased by $\frac{1}{\text{Cos}\,\theta}$ where θ is the angle between the towing cable and a supposed anchor cable. For the latter we will take the cable from an anchor cast 20 fathoms from the pontoon in 6-ft. of water. The following figures give the relations between speeds and anchor pulls.

	Speed.	Measured pull. Lbs.	θ	Anchor Strain. Lbs.
Down 1	5·35	280	7°	314
Up 2	4.6	190	7°	213
Down 3	6.0	336	5°	365
Up 4	5·3	215	3°	226
Down 7	4.1	196	2°	203
Up 8	5·4	238	4°	255
Down	7.1	700	7°	785
Up	8.6	756	7°	849

These results may be indicated by a graph, by eliminating unreliable figures. It should be realised, however, that the experiments were not designed with a view to testing this particular point, and that the results can only be taken as a broad general indication of what may be expected to happen. It will be seen that in currents of over 5 miles per hour the anchor strains increase rapidly for small increases of speed of current.

This is for a single pontoon; in the case of a bridge with each pontoon anchored the strains would be increased, and in the case of heavy bridge they would be still further increased.

We can now summarise the conclusions arrived at from these tests:—

(*a*) The scow bow (Fig. 6) is the most suitable bow for the steel pontoon.

(*b*) A prow bow does not appear necessary in currents of under 8 miles per hour; for currents of over 8 miles per hour further experiments are necessary.

It will be seen from the above report that the ideal form of bow was unpracticable, owing to the loss of buoyancy and consequent lengthening of the boat thereby involved.

Further, the necessity for waterway between pontoons no longer exists, for the scow bow enables the pontoon to ride on the water, and when pontoons with scow bows are placed close together the

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water goes under the pontoons, whether the stem is bow-shaped or square, and there is a tendency to lift the pontoons.

Former experiments with heavy pontoons at Christchurch and recent experiments by the French are in accordance with this fact.

These recommendations were accepted. Two detailed designs for a metal pontoon were prepared accordingly—one with straight sides and a central girder, the other with slightly curved sides and designed to distribute the strength throughout the structure. The dimensions of these were 21-ft. long, beam 5-ft. 6-in., depth 2-ft. 11-in.

It will be observed that this section did not admit of coupling with the existing service pontoon, and in the case of the central girder type a central coupling was necessitated by the design—as will be seen later, this factor has proved a serious difficulty.

The departure from the standard section was unavoidable, because a greater depth was required to provide the necessary girder strength. The beam was consequently reduced to avoid superfluous weight, the necessary buoyancy having been provided by the increased depth, but this reduction of beam was found in practice to render the pontoon unstable to an undesirable extent.

The two designs were submitted to Professor Inglis for technical criticism, and he reported in favour of the central girder type with certain modifications.

Material.

The next subject for consideration was the material, especially for the skin, in view of corrosion difficulties.

The different materials considered were a copper steel mixture, stainless steel, soft chrome steel, and stainless iron.

Corrosion tests were carried out upon "Galahad" stainless steel, air hardened steel, air hardened and tempered steel, unpolished pickled sheets supplied by Brown, Bayley and Co., and two steels containing ½ per cent. and 2 per cent., respectively, of copper.

Of the above materials the air hardened and tempered sheets appeared to stand best, while the "Galahad" appeared most suitable for framework.

The "copper" steel which is not seriously (as is the case of "Galahad") greater in price than mild steel, compared very favourably with the latter, while its strength was stated to be much greater, but was not tested.

Improved copper steel sheets and sheets of 12 per cent. to 14 per cent. chromium steel supplied by Firth were tested subsequently.

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Trials of several preservative compositions were made simultaneously with those of the steels described above.

Three months' immersion of plates so coated and exposed between wind and water indicated that a material diminution of rusting was obtained both on mild steel and on the other materials; the improvement in the case of mild steel was very marked and showed these compositions to be superior to ordinary paint.

All the above tests took a considerable time, and the designs and construction of the steel pontoons proceeded without awaiting them; steel of B.E.S.A. specification for "S 3" was specified for sheeting and frames, and of B.E.S.A. specification No. 15 for structural steel. After certain slight modifications the trial pontoons were delivered in March, 1923, and having been ordered in advance of the preservative tests, were painted with red oxide.

It may be asked if consideration was given to the idea of using aluminium or an alloy thereof either for sheets or for framing.

Against this there were two reasons: Firstly, that the metal pontoon was always regarded as a makeshift substitute for one of wood, only to be provided where the demand was so great that rapid output of wooden pontoons would be impracticable, and, secondly, that under such circumstances, as proved in the Great War, the provision of the material might be very difficult in view of more urgent requirements for other services.

More immediate objections were the extreme difficulty of providing a non-corrodible alloy or a practicable protective covering.

It is possible, however, that the use of this material may have to be reconsidered, as it has since appeared that the weight of a steel pontoon, in other respects suitable, renders it difficult to handle.

The two trial steel pontoons were tested in March, 1923, and were found to be water-tight and strong enough for the work; they gave 7¼-in. mean freeboard for a 5-ton load.

The main defect of the steel pontoon was its weight (1,792-lbs.). The couplings also presented considerable difficulties. They were strong enough under test, but on account of the central position of the lower coupling it was extremely difficult to couple up on dry land and impossible when the pontoons were afloat. No satisfactory type of coupling has been found, and Messrs. Thornycroft could suggest no method of lightening the steel pontoon, while retaining the present beam and other dimensions.

CONSUTA WOOD PONTOONS.

While the service pontoons were being decked, attention was drawn to a new form of plywood called "Consuta," in which the

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layers of wood are sewn together as well as cemented, and Messrs. Saunders, of Cowes, re-covered a service pontoon with this material for trial. Investigations were set on foot as to the history and durability of boats constructed of this material, especially in hot climates. Later, Mr. Saunders offered to make, free of charge, a new pontoon entirely covered with this material, claiming that the use of this material would enable a considerable lightening of the framework. This offer was accepted and a second pontoon ordered. The dimensions and calculated weight and buoyancy of this pontoon were (See Plate I, Fig. 1) :—

Length	21-ft.
Width	6-ft. (including handles).
Depth	2-ft. 8½-in.
Buoyancy	5.8 tons with 8-in. freeboard.
Weight	1,250-lbs.

Owing to certain modifications while under construction, the actual weight, when delivered, was 1,350-lbs. as compared with 1,200-lbs. for two sections of service pontoon, while the buoyancy test gave the following results :—

Weight of Superstructure and Load in Tons.		Freeboard in Inches.		
Total.	On each Float.	No. 1 Float. (mean).	No. 2 Float. (mean).	Calculated from displacement curve.
3.25	1.62	21.6	21.2	22
8.25	4.1	11.5	11.0	12
10.5	5.25	6.8	7.3	7.5
12.5	6.25	4.8	5.5	4.2

Test of Couplings.—Two pontoons were coupled end to end, and a nett load of 12 tons 7 cwts., which introduced a strain of 8½ tons on each coupling, was applied to them for over 12 hours without damage.

When fully loaded in heavy bridge, the maximum strain on the couplings would be 7 tons, so the test was a 20 per cent. overload. The mean freeboard was 5-in.

Investigations into the merits of consuta wood as a material showed that, though in seaplane construction it has proved un-

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suitable, satisfactory results over a long period of use in motor boats, in various climates, including 12 years in Egypt, had proved its durability.

Special dry and moist heat tests were also carried out with satisfactory results—and also practical comparisons with other forms of plywood, very much to the advantage of consuta.

The following tests of the effect of rifle fire were carried out :—

" (i) at 30 yards range above water line.

(ii) at 30 yards range below water line.

(iii) at 100 yards to 300 yards above water line, normal to the surface.

(iv) at 100 yards to 300 yards above water line, obliquely to the surface.

" *Above water line.*—In all cases above water line the ingoing bullet left a very small hole, which partially closed up at once, and later; when the float was immersed, closed up yet further. The outgoing bullets made jagged holes about ¾-in. x breadth of bullet.

" *Below water line.*—Ingoing bullets made very small holes when the float was filled with water, to the same depth as the immersion. Ingoing bullets aimed below water line into the empty float made jagged holes about 1-in. x ½-in. In no case was an outgoing hole made by a bullet aimed below water line.

" *Rates of leakage.*—After plugging certain of the holes made, the following rates of initial leakage ' in ' were measured :—

" (*a*) Ingoing holes above water line (Av.) 1.5 g.p.h.
" (*b*) Outgoing ,, ,, ,, ,, 140 ,,
" (*c*) Ingoing ,, below ,, ,, 168 ,,
" (*d*) ,, ,, ,, ,, ,, 8.5 ,,
(float flooded.)
" (*e*) Outgoing holes below water line, none obtained.

" The worst case would probably be that for a bullet aimed just below water line in such a way that both in and outgoing holes were made. In this case the initial flow would probably be in the region of 300 gallons through the pair. The best way of stopping small holes would appear to be by small wooden cones 3-in. x 0-in. x ⅜-in.; and larger ones with lathe 1-in. x ½-in. section, which could be quickly shaped with a knife, and driven in from either inside or outside the pontoons."

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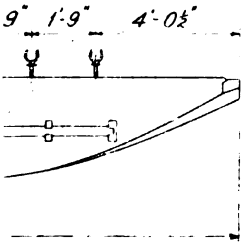

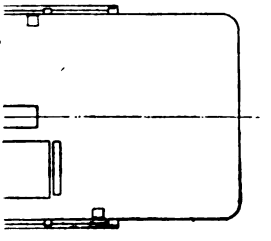

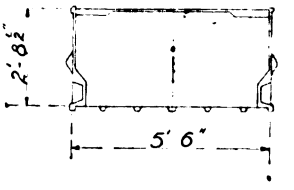

— PONTOON —

FIG I

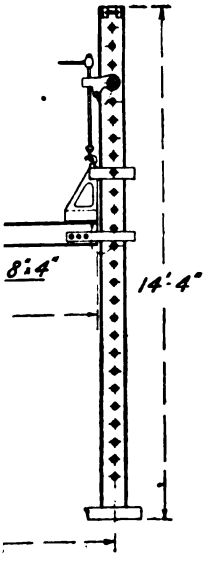

PLATE I.

TLE —

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Two additional pontoons were ordered in September, 1922, with modifications in certain scantlings, whereby it was hoped to reduce the weight to about 1,200-lbs. These were delivered in January, 1923; they weighed 1,288 and 1,316lbs. respectively, and underwent satisfactory tests.

The handles in the original design were wooden bars projecting out from the sides and housing into sockets when not in use—very convenient for carrying, but liable to injury and difficult to repair. These were replaced in the second pair by a continuous bar along the side of the pontoon. (See Plate I, Fig. 1).

The new shape bow involves a change of position of the centre of buoyancy, as the load varies along the length of the pontoon when used singly, and consequently the roadway cannot under all conditions of loading remain level in a transverse direction. The results of trials for the best position for the saddle found one such that no load gave a difference of 2½-in. immersion by the head, while infantry in fours caused a difference in the opposite direction of 3-in.

In loading a bridge on 12.4.23, with a fully loaded 3-ton lorry and a dead weight of 1 ton, the couplings opened, necessitating re-design.

Four hooks in mild steel were prepared and tested at King's College (London) and from the results a fresh design was prepared, calculated to stand without deformation a strain of 14 tons, giving a factor of safety of 2 on the elastic limit.

The attachment of the hook and of the pin and its attachment were also re-designed with the same object—and by the end of August, 1923, a fully loaded 3-ton lorry had crossed the pier, to which a dead load of 2 tons had been added, 440 times without signs of strain or any appreciable leak.

Up to the date of writing probably some 15,000 loaded lorry crossings (6,000 with a 2-ton overload) have been made without injury.

For the complete pontoon the only details remaining to be settled were the pump, the hatches and the positions of the row-locks.

For rowing the pontoon is somewhat awkward, both from being decked and from the forward slope of the deck when unloaded. It was found after trials that the number of side rowlocks in the first pontoon, six, had to be increased to eight, both for the above reasons and because, in raft, some of those on one side could not be used. The eight side rowlocks were finally "staggered" to allow eight rowers all to row together. (See Plate I, Fig. 1).

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This re-arrangement of rowlocks necessitated altering the hatches. The position of the hatches is a result of a compromise. The difficulty was so to arrange access to each section of a pontoon that it should be accessible in light and in medium or heavy bridge. One hatch was originally provided in each section of the pontoon, but no disposition of them could be found to render both accessible under either circumstance; so it was decided to provide an extra hatch for the stern half. (See Plate I, Fig. 1).

As regards the pontoon itself the foregoing completes the history; it remains to deal with the superstructure.

The design of superstructure for the 21-ft. span that had been selected was based upon the following assumption for loads—

(1) An impact allowance of 50 per cent. for lorries and other fast moving traffic; 25 per cent. for tanks.

(2) A factor of safety of two for the heaviest loads intermittent and discontinuous.

(3) A factor of safety of three for continuous loads and any large single load likely to be frequent, *e.g.*, lorries.

On a first assumption of 12 bearers for heavy bridge and six for lorry bridge, the maximum equivalent distributed dead loads were calculated at 6 tons (medium C Tanks) and 5.8 tons for lorries on any one joist—the unloaded span was taken as 20-ft. 6-in. This involved (using 9 x 4 joists) stressing a joist up to 15 tons per square inch.

Professor Inglis, to whom this was referred, advised against this risk as almost inevitably involving permanent set—but suggested that, for our purposes and speeds, 33 per cent. impact would suffice—also that the actual distribution of the loads on the joists was obscure.

This led up to preparations being made for more precise tests of this action, which will be described later.

To be continued).

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MEMOIR.

MAJOR RICHARD VICTOR MORSE.

The death of Major Richard Victor Morse, D.S.O., who died at Leeton on 26th January, removes one of Sydney's most prominent engineers, and a distinguished soldier. Major Morse contracted an illness while engaged in an inspection tour in the Murrumbidgee irrigation area in connection with the electrical branch of the Public Works Department. He was a son of Mr. Richard Morse, formerly of the designing department of the Sydney Harbour Trust. Educated at the Sydney Grammar School and Technical College, he entered the service of the Standard Waygood Company, and in 1905 proceeded to England, and joined the engineering works of Dick Kerr and Company, Preston, Lancashire, to obtain further practical experience.

Returning to Sydney after four years in England he eventually entered the electrical branch of the N.S.W. Railways and Tramways, under Mr. O. W. Brain. In February, 1916, he left for active service as a captain in the Mining Corps, and in France was promoted to the rank of major, and placed in command of a specially formed unit termed the Australian Electrical and Mechanical Mining and Boring Company, the only electrical unit which did front line work. For his services while in command of this unit he was awarded the D.S.O., and twice mentioned in despatches. This unit also obtained the almost unique distinction of being mentioned by the Commander-in-Chief, Sir Douglas Haig, on a "Special Order of the Day," on December 4, 1918. Major Morse returned to Sydney as O.C. troops on the transport *Kanowna* in October, 1919.

In February, 1920, Major Morse went to Tasmania, and joined the hydro-electric department of that State. After two-and-a-half years' strenuous work there he was appointed to the position of chief assistant electrical engineer in the New South Wales Public Works Department.

Major Morse was severely gassed on a number of occasions while on active service, and since his return to Australia had suffered from gradually failing health.

Major Morse was a member of the Institute of Mechanical Engineers, and an associate member of the Australian Institute of Electrical Engineers.

He is survived by a widow and three young children, the eldest of whom is 11 years of age.—*Extract from the "Sydney Morning Herald" of 28th January*, 1925.

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BOOKS :

THE ROLL OF HONOUR OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

THE Corps has received from the President and Council of the Institution of Electrical Engineers a copy of their Roll of Honour for preservation in our Library in London. The Roll, which has taken over three years to prepare, has been edited by Lieut.-Colonel W. A. J. O'Meara, C.M.G. (late R.E.), under the instructions of a War Memorial Committee, with the late Mr. C. H. Wordingham, C.B.E., as Chairman and Mr. P. F. Rowell as Secretary. In an Introductory Chapter Colonel O'Meara discusses the Origin and Causes of the Great War, and this is followed by the Roll with full obituary notices, and in most cases also portraits of the 162 Members and Associates who gave their lives in the War. It is natural that very many wear the uniform of the Royal Engineers. The Roll includes the names of two regular officers of the Corps, Lt.-Col. A. H. Dumaresq and Major A. Gardiner, and among the Territorial members the most distinguished is Colonel Bertram Hopkinson, C.M.G., F.R.S., whose father raised the Tyne Electrical Engineers and who himself joined the R.E. Volunteers as long ago as March, 1896. It is hoped that we may be able to reproduce the obituary notice of this distinguished officer in our next issue.

F.E.G.S.

HISTORY OF THE GREAT WAR. MILITARY OPERATIONS, FRANCE AND BELGIUM, 1914.

By BRIGR.-GENERAL J. E. EDMONDS, C.B., C.M.G. (Macmillan & Co.) 12/6 and Maps 5/6.

THE British Official Account of the Great War is now to consist of approximately ten volumes, viz., for 1914, two; for 1915, one; for 1916, two; for 1917, two; and for 1918, three.

In view of the special interest relating to the operations in 1918, it has been decided to speed up the volumes for that year, but it is disappointing to learn that, presumably on the score of expense, the narrative is to be further condensed, and that 1918 will be dealt with by another pen than of Brigr.-Gen. Edmonds. We are, however, fortunate in having his experience, and the plan he has adopted in the first two volumes will doubtless be followed. His well-known book on the Civil War in the United States, written with the collaboration of Mr. W. B. Wood, is a masterpiece, in one volume, of the art of eliminating the non-essentials and at the same time by copious references in footnotes enabling the student to know where to find the details if further information is required.

The second volume for 1914, the subject of the present review, completes the narrative of the operations of the British Army down to

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the close of the great battles in Flanders—La Bassée, Armentières, Messines and Ypres—which continued without a break from October 10th to November 22nd, 1914. In it Brigr.-Gen. Edmonds confines himself, as in the first volume, strictly to accurate narration of the facts; and by the omission of all criticism he leaves it to the reader to draw his own conclusions. To the military student this is easier than to the uninitiated, but even to the latter the book is full of suggestion if carefully read. To those who know the writer the brief statement of a fact may imply much more than meets the eye, and where opportunity for criticism is almost obvious, its omission is suggestive. In the first volume Brigr.-Gen. Edmond's method re-established without question, the reputation of General Sir Horace Smith-Dorrien, and dissipated once for all the fog lying over the Battle of Le Cateau. In the second volume the same method will compel the historian of the future to probe more deeply than is permitted to Brigr.-Gen. Edmonds, into the question whether the co-operation of the Allies could not have been more complete in the early stages of the war. In his review (*R.E. Journal*, March, 1923) of the first volume, Major-General Thuillier was led to ask some pertinent questions as to the conduct of the Battle of the Marne; in the second volume there is ample material for similar questions, particularly in regard to the operations resulting in the fall of Antwerp and the responsibility of each of the Allies for that disaster. In this connection it is satisfactory to know that, in so far as it has progressed, the French Official Account is straightforward and impartial, and that the authorities charged with the compilation of the official histories, both in France and Belgium, have willingly supplied all the information asked of them.

It will not be out of place here to suggest that in future volumes space might be found in the appendices for an outline of the contemporaneous operations, on the Western Front and elsewhere, in order that the reader may have some idea, without having to refer to other publications, of the general situation on a given date, and of the factors which are likely to have influenced the Supreme Commands of the Allies, and of the enemy, in any particular phase, especially as regards the information *available at the time* as to the enemy and allied strengths in the various theatres of war.

It would, for instance, be interesting to know what prevented more reinforcements being sent, or what delayed the despatch of those that were sent, to the northern flank of the Allied line in the early days of October, 1914? Not only our Allies, but we ourselves, should have more definite knowledge of the intensity of the effort on our respective fronts, if only with a view to arriving at an earlier decision in the future as to the absolute necessity for unified command in all operations where allies are involved.

It is difficult to review the "Introductory Chapter," in that it was originally intended to devote a whole volume to an account of the expansion of the Army and the preparations which were made at home and in other parts of the Empire during the months which immediately followed the outbreak of hostilities. The material collected has been condensed into a single chapter, and the reader will be well repaid by reading it through. Brigr.-Gen. Edmonds briefly records the various

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measures that were taken, but only in one or two instances does he allow himself the luxury of criticism. He mentions that there was a fortnight's delay in authorizing the enlistment of ex-N.C.O.'s of the Regular Army, when instructors and men used to discipline were in such urgent demand. He then puts it on record that "in the middle of September, 1914, when the total of recruits reached 500,000, it was deemed advisable that a *brake should be put on recruiting* (the italics are his), and the standard of physique was raised. This measure had the effect of reducing the stream; so much indeed that when organisation had been introduced, although the restrictions with regard to physique were removed on October 11th, it became necessary to adopt special measures to stimulate recruiting." Consequently it was not until February 23rd, 1915, that the million mark was reached, and not till September 3rd, 1915, that the figures reached a million and a half.

Brigr.-Gen. Edmonds recalls the fact that "on the very day, August 7th, 1914, that Lord Kitchener called for the 'First Hundred Thousand,' offers of assistance came from the Dominions Overseas. The War Office accepted 20,000 men from Canada, 20,000 from Australia and 8,000 from New Zealand." The mistake made in the South African War was not perhaps repeated, but in view of the enthusiasm with which the call to aid the Mother Country was received in the Dominions, it is hard to understand why the contingents were limited in the first instance. The effect was probably similar to what occurred when the "brake on recruiting" was applied in the home country.

The shortage of gun ammunition is necessarily dealt with at some length, but the official historian abstains from apportioning the responsibility for the shortage or the delays that occurred in remedying it. It seems strange that the authorities were so slow to profit by the numerous pre-war reports of officers who were attached to the Russo-Japanese Armies or who attended the Autumn Manœuvres of the great Continental armies after the Russo-Japanese War. Those reports were printed, and reiterated the need of increased ammunition supply for q.f. field artillery, the provision of H.E. shell for field howitzers, the great increase in the number of machine guns, the advent of the trench mortar, and the revival of the hand grenade. The Germans profited by similar reports by their military attachés; we did little or nothing. The constant cry for economy in the Army Estimates was undoubtedly responsible for some of the failure, but there seems to have been a general disinclination to face the facts.

It is said that the South African War woke us up from the effects of a long peace. But did it wake us up as a nation? In the Army, in organization, in staff duties, in infantry training and musketry, great improvements were effected. The same measure of progress did not show itself in material. When the money was insufficient to go round the provision of material was perhaps sacrificed to the improvement of the personnel. We muddled through once more, but at what a sacrifice! What can we do now to prevent the nation being blinded in the future by the dream of a prolonged peace? The story of Lord Roberts' vain efforts (mentioned by Brigr.-Gen. Edmonds) to wake the nation up to a realization of the dangers ahead must never

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be forgotten. Brigr.-Gen. Edmonds, in a short paragraph, describes the success of the mobilization arrangements and the Home Defence Scheme. It says much for the laborious care with which the Officers, staff and regimental, of the Regular and Territorial Armies and the Special Reserve had prepared the various schemes in time of peace, in conjunction with the General and Administrative Staff at the War Office and the Railway Companies, that the arrangements were carried out without a hitch. Mention is also made of the effective measures taken to deal with enemy agents, which resulted in completely paralysing the German Intelligence Service, and spreading a veil over the British effort for a considerable period after hostilities commenced.

Returning to the Territorial Force. By the end of 1914 the Territorial Force, which, on 4th August, was some 5,700 officers and 150,000 men short of its establishment of 15,977 officers and 401,556 other ranks, had more than doubled its original strength, and practically all the new men had undertaken the obligation to serve wherever they might be required. And this, in spite of the inevitable competition with the New Armies in attracting recruits, and the fact that the War Office had a preferential call on the resources of the country in clothing, boots, and other necessaries. The lesson has not been forgotten, and the recent decision to base the expansion of the Army in a future crisis on the Territorial organisation is the outcome of our experience in 1914.

The housing of the troops is passed over in a few lines, but it would be instructive for Sappers to have access to the original draft. " The accommodation in barracks at the time of mobilization was sufficient for 174,000 single men ; it was increased to 262,000 by clearing out the families of soldiers from the married quarters and using every accessory building that could be made available. Even this development provided only for a small portion of the total increment of recruits, and though large numbers were placed under canvas and others housed in hired public buildings, as many as 800,000 men had to be quartered at one time on the population in billets. The late Sir George Scott-Moncrieff has done much to enlighten us on the difficulties, and the measures he took to surmount them by hutting. Judging by our experience on the L. of C. and at the front in France, it was many months before wasteful competition in the purchase of materials was got rid of by a controlling authority.

The chapter concludes with a brief reference to Supply & Transport, from which it is evident that the provision of Supplies was ably handled ; the Remount system inaugurated before the war stood the test well on the whole, though the supply of grooms and the provision of shelter for the animals was inadequate at first ; and steps to remedy the shortage of motor vehicles suitable for the New Armies were taken in hand promptly.

The Antwerp Campaign. The fall of Antwerp, involving as it did the loss of the Belgian coast and the ports of Zeebrugge and Ostend, was a far-reaching disaster to the Allied cause, insomuch as these ports became the principal bases for the submarines of the German Fleet. To an amphibious Power it was, from all points of view, essential that the

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Belgian coast should not fall into enemy hands. It is not surprising, therefore, that the British Naval and Military Authorities made a desperate effort to prevent the disaster, but it was made too late. The great entrenched camp of Antwerp was a dangerous menace to the German communications only so long as there were field troops in it. It was soon obvious that unless the fortress could be included in the general line of the Allied front, in the same manner as Verdun, Nancy and Belfort, it was sooner or later bound to fall, and the sooner if the 12-inch Skoda howitzers (the existence of which should not have been a surprise—if it was) and the German heavy mortars were employed against it.

Gen. Joffre's plan was to push forward his left wing, outflank the German right flank, and so relieve the pressure on the fortress. Its premature fall seems to have been left out of his calculations. The enemy's super-heavy artillery became available after the fall of Maubeuge, on September 7th.

The bombardment of the outer forts commenced on September 28th, and its inevitable result was apparent on the following day. The bulk of the Belgian Field Army was withdrawn westwards behind the line Ghent-Selzaete, by the night of October 8/9th, and the city capitulated on October 10th. It is left to the historian of the future to decide whether the Allies could have done more to avert the disaster.

The forts of Antwerp were of obsolete type, and were mere shell traps. "After the siege of Port Arthur, it was known that the casemates and magazines were not 6-inch shell proof, and although steps had been taken to strengthen some of the shelters with a layer of concrete," the work was badly done and the result ineffective. A German report says: "Nowhere had measures been taken for ventilation nor for dealing with the invasion of the cupolas by deleterious gases." Probably also, as at Liège, the gun crews were driven out of the cupolas by the gases liberated when the breech blocks were opened to re-load. Something of the same sort occurred later in some of our concrete machine-gun posts. There was no smokeless powder, every gun was given away by its discharge. There were no high explosive shells.

"The Belgian Engineers had done an immense amount of work subsequent to the commencement of hostilities. Inundations had been made; field defences between the forts constructed; and the foreground cleared," with ruthless regard to the amenities of the suburbs of a wealthy city. But the clearing had done more harm than good, as it rendered the forts clearly visible to the enemy, who, owing to the enclosed and timbered nature of the surrounding country, remained hidden. The trenches were little more than a foot deep owing to water near the surface, and the breastworks had no shell-proof cover, even against field guns. There was no fortress telephone system, and no means of observing the fire of the guns. The armament was inadequate; only one German battery was within range of the fortress guns.

Brigr.-Gen. Edmonds goes to the root of the trouble when he writes: "It would appear that the great mistake of all the Allies as regards fortresses in the early days of the war, was that they considered any second line troops good enough to hold and defend them." He instances

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Namur, Maubeuge, Novogeorgeviesk and Fort des Romains, as compared with Grand Couronné and Verdun, and reminds us that the Germans came to the same conclusion after 1870-1. Further, he quotes from a written statement to the Belgian Court of Inquiry—" the lamentable state of the Belgian troops, most units having ceased to exist as formations and being no longer in a state to offer effective resistance . . . ., and the men of the (British) Naval Division being for the most part untrained and badly equipped." Brigr.-Gen. Edmonds draws the obvious deduction :—" Experience went to show that the best troops, or, at any rate, a good proportion of young troops, are required to conduct an active defence and resist the moral effect of being abandoned by the Field Army, the strain of heavy shelling, and the destruction of works supposed to be impregnable."

The position of the fortress, close up against the Dutch frontier, proved to be very unfortunate for the Allies, for as soon as the enemy drove back the Belgians from the line of the R. Dendre and across the R. Scheldt, there was only a narrow " corridor "—13 miles wide at Termonde—by which help could come or escape westwards be effected.

The original German plan was to attack the fortress with eleven divisions from the east, where no inundations were possible ; but the investing forces, the equivalent of only six divisions, were given the extra tasks of guarding the Tirlemont-Brussels section of the Liège-Brussels railway (absolutely vital for the supply of the German right wing) and of preventing communication between Brussels and the Belgian Army. " These various tasks could only be solved by an attack from the position held by the Germans south of Antwerp. The general idea was to break through the outer line of forts at one place due south of the city and then extend the gap northwards. A covering line was formed between the R. Grande Nethe and the R. Scheldt, just in front of Mechlin (Malines), which was occupied by three German divisions who advanced from their entrenchments on the north side of Brussels and drove back the Belgian outposts some four or five miles." The heavy artillery was then deployed east and south of Mechlin. It consisted of 160 heavy and 12 super-heavy guns and howitzers. The bulk of the Belgian Field Army (six divisions) was south of Antwerp, with one of these divisions and the Cavalry Division in the vicinity of Termonde, at the junction of the Scheldt and Dendre rivers, south-west of the fortress.

On September 25th, that is shortly before the bombardment of the outer forts was commenced, the Belgians attempted one sortie. This, originally planned on a large scale at the urgent request of Gen. Joffre, to threaten the German communications, was subsequently limited, owing to the obvious preparations for immediate attack. It came to nothing, and was easily defeated by a Landwehr brigade supported by the fire of the heavy artillery.

Later, on October 5th, when two battalions of a German Reserve regiment crossed the R. Nethe a mile below Lierre, by means of a trestle bridge prepared on barrels in a convenient creek near at hand, the Belgians lost a great opportunity for counter-attack. Supported by artillery fire, though in a critical position, the two battalions managed to hold on until reinforced at nightfall by two more battalions. A counter-attack

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was ordered, but owing to the orders not reaching some of the units (including the British Marine Brigade) in time, it was limited to a few Belgian units, who, though successful at first, were unsupported and driven back seriously shaken. During the next day (October 6th) the Belgians retired from the line of the R. Nethe to another partially prepared position halfway between that river and the inner line of forts, and the Germans were free to push their heavy artillery forward to positions whence they could bombard the inner forts and the city itself.

On October 7th the Germans succeeded, after several unsuccessful attempts, to push a Landwehr brigade across the Scheldt at Schoonaerde (9 miles above Termonde) in boats in the face of the Belgian troops, which had been reinforced on October 6th by another division from Antwerp. On October 8th two more brigades crossed the Scheldt, and in the course of the day, opposed only by Belgian flank guards, these three pushed their advanced guards nearly 8 miles, towards Lokeren, where they were about the same distance from the Dutch frontier. Brigr.-Gen. Edmonds remarks: " the action may seem extraordinarily bold for a small force, but no serious opposition was expected, as the German aviators had reported in the afternoon that the roads leading west from Antwerp were in general still clear." It seemed to the German Commander that no effort to escape was being made by the Belgian Army, and that he might proceed to invest the fortress on the western side. As a matter of fact, by the night of the 8th October, the bulk of the Belgian Army had escaped and were west of the line Ghent-Selzaete, leaving only the 2nd Division, some fortress troops and the R. Naval Division to follow. Brigr.-Gen. Edmonds gives a graphic account of the tragedy of the three battalions of the 2nd Naval Brigade, and of the Portsmouth R.M.L.I. Battalion, which formed the rear guard; and describes how the remainder of the Royal Naval Division, the 2nd Belgian Division, and the bulk of the fortress troops effected their escape during the night of the 9th/10th October.

Could the Allies have acted more promptly? Brigr.-Gen. Edmonds says: " It was obvious that a strong British force landed at Dunkirk or Ostend would serve General Joffre's offensive plans if things went well with the Allies, for it might be in time to out-flank the Germans; and if the enemy's movements were too rapid for this, and Antwerp were in danger of being isolated, it would be on the spot to assist the Belgians to cover the retreat of their Field Army."

Early in September the British General Staff had suggested a movement from Dunkirk and Calais; and on September 16th General Joffre, acting on this idea, had asked that all available British troops might be sent to these ports to act against the enemy's communications. A Royal Marine Light Infantry Brigade, the Oxfordshire Hussars Yeomanry, and a detachment of R.E. had accordingly been sent to Dunkirk on 19/20th October, under the Command of Brigr.-Gen. Aston, and under the control of the Admiralty. It was all along the intention of the British authorities—should circumstances permit—to suggest to the French the transfer of the whole of the British Army in France from the Aisne to the neighbourhood of Calais, but it was not till General Joffre visited British G.H.Q. on September 26th-28th, that he gave his

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consent, and indicated Lille as the place of concentration of not only the original B.E.F., but also for that of 7th and 8th Divisions when ready, and the Indian troops which had commenced to disembark at Marseilles on September 15th. Brigr.-Gen. Aston's force, which by energetic action might well have been made to appear to German eyes as the advanced guard of a much larger force of Territorial and newly-raised troops, remained in the neighbourhood of Dunkirk till September 28th, when one battalion was at the request of the French sent to Lille. The command then was assumed by Brigr.-Gen. Paris, owing to the illness of Brigr.-Gen. Aston, and on September 30th, headquarters and three battalions were moved to Cassel, the recruits being left at Dunkirk. The Marines patrolled the neighbourhood on cycles and in motor buses, whilst Commander Samson's armoured cars working with local French troops, searched the country further east and cleared it of German Cavalry patrols. The German I and II Cavalry Corps were then approaching Lens, 30 miles S.E. of Cassel.

It would seem, therefore, that from September 18th, when British G.H.Q. directed attention to a probable intensifying of the German effort against Antwerp, till September 30th, the possibility of its early fall, and the isolation, if not capture, of the Belgian Field Army, had not impressed itself on either the British or French Supreme Commands. At all events, no steps had been taken to try to avert it or to help the Belgians to prolong the defence.

On September 29th Belgian Headquarters began definite preparations for the withdrawal of the Field Army, it being their intention to leave the fortress troops (some 80,000 men) to continue such defence as was possible.

On September 30th the Belgians appealed to the Allies for help, but it was a message from the British Minister on October 2nd, that awoke the Allies to the imminence of the danger if the Belgian Field Army was prematurely withdrawn from Antwerp. Reading Brigr.-Gen. Edmonds' account, it would indeed seem as if General Joffre had based all his plans solely on the successful advance of the Allied left wing. Nor would it appear that the British Government had visualized the possibilities of an early collapse. For the reply sent on October 2nd/3rd to the Belgian appeal read as follows: " urged them to hold the fortress, if possible, until the issue of the main battle in France had been determined, and in any case to continue the struggle with the Field Army, if only for a few days. Immediate help was promised in the shape of the R.M.L.I. Brigade (then at Cassel, Lille and Dunkirk), but hopes were held out that other troops might be sent from the main Armies, and if possible from England also."

The British Government immediately communicated with the French Government, and ordered certain moves to be carried out at once. On October 3rd the British R.M.L.I. Brigade was moved by rail to Antwerp, and reached that place at 1.0 a.m. on October 4th. A battery of artillery was also sent direct, and at Mr. Winston Churchill's instigation, two naval brigades were ordered to Dunkirk. This was moral support, but little else, for by that date hopes of saving the fortress had nearly disappeared, and it was merely a question of what could be done to assist

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in the withdrawal of as many Belgian soldiers as possible from the fortress before it fell.

We must remember that at this critical moment the B.E.F. was only just about to leave the Aisne. The leading Corps (IInd) was to entrain on October 4th, on which date the 7th Division and the 3rd Cavalry Division, formed in England mostly of troops relieved from Overseas garrisons, would be nearly ready to move. But in England there were " thirteen Mounted Brigades (T.F.) and thirteen Territorial Divisions (including two warned for India, the 42nd had already gone to Egypt) ; sufficient men had been recruited to form twelve New Army Divisions, and the 8th Regular Division was in process of formation." However, the same reluctance on the part of the Government to part with its troops which delayed the dispatch of the 4th and 6th Divisions of the original B.E.F., in spite of the fact that two Territorial Divisions had unexpectedly not been required to proceed to Ireland on mobilization, again made itself felt. It was only Lord Kitchener's insistence that induced them to allow the 7th Division and the 3rd Cavalry Division to go to Belgium, and it was Mr. Churchill who stepped into the breach by offering the two Naval Brigades of the Royal Naval Division, which were not nearly as ready for service abroad as the thirteen Territorial Divisions. Dispatched at a day's notice, the two Naval Brigades disembarked at Dunkirk on the night of the October 4/5th, and were in action at Antwerp on the evening of October 6th. The 7th Division landed at Zeebrugge on October 6th and 7th, and the 3rd Cavalry Division reached Ostend on October 8th.

Now as to the French effort. After the Belgian appeal for help, on September 30th, the British Government asked General Joffre to send one Regular Division. " He did not see his way to send Regulars as all his troops who had been brought to the left wing were heavily engaged." All he could do was to suggest—not promise—one Territorial Division to arrive at Ostend from October 6th to 9th, and a Marine Brigade from Havre in ten days' time. " Lord Kitchener considered that the force offered was inadequate to raise the siege, and informed the French that if nothing more could be done, it would be better to retain the troops and not risk them against the superior German forces." That meant that Antwerp was to be abandoned.

If the Germans could transfer several Corps from other parts of their line to their right, as they did, it is difficult to understand why the Allies could not have sent more than the three British Corps and two Cavalry Divisions ; for General Joffre's plan was based solely on the ability of the Allied left to turn the German right flank, and for this superior numbers were obviously required. No doubt the authorities in Paris and Bordeaux were as short-sighted as those in London.

In describing the operations that ensued, Brigr-.Gen. Edmonds pertinently remarks that : "the situation, on October 7th, was somewhat complicated, *and there was no Supreme Commander in charge of the operations as a whole* (the italics are not his). The garrison of Antwerp (80,000 men) was, with the Belgian 2nd Division and the R.N. Division, holding the line of the inner forts (southern sectors) ; the Belgian Field Army (six divisions and a cavalry division, 65,000 men, less the 2nd

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Division and presumably casualties) was moving away westwards from Antwerp, between the coast and Ghent; a French Naval Brigade (6,000 men) was on its way by rail from near Paris to Ghent, where there was already a small mixed Belgian force of all arms, 4 battalions of partially trained Belgian volunteers, and two companies of the French 5th Territorial Regiment; the newly landed British 7th Division was concentrated at Bruges, waiting for the 3rd Cavalry Division, which was in transports off Dover awaiting a naval escort to take it to Ostend. Between these forces and the left of the general line of the Allies, which was near Lens, some fifty miles south-west of Ghent, covered by French Cavalry extending to near Hazebruck, three German Cavalry Divisions were attempting to move westwards. Of the original B.E.F., the 2nd Corps was approaching Abbeville by rail; the 3rd Corps was entraining near Soissons to follow it to Flanders; the 1st Corps was still in position on the Aisne; the 1st and 2nd Cavalry Divisions were on the march north behind the French line, and, being delayed one day at Montdidier, the leading (2nd) Division was not to reach St. Pol till the 9th October.

A pretty problem of time and space, with troops of three nations involved! For the late Lord Rawlinson and the late Major-General Sir Thomas Capper, it was indeed an anxious period, but nothing to what was to follow when the IVth Corps had succeeded in finding itself in the general Allied line east of Ypres.

Antwerp surrendered on October 10th. The Germans stated that surprisingly few prisoners were captured beyond wounded men and detachments found in some of the forts.

"By a prodigious effort the Belgian Army had baffled its colossal adversary and finally escaped him, but now, after more than 2 months of uninterrupted operations and all the moral suffering which the gradual abandonment of national territory brought with it, time was required for rest and re-organization." This, however, was not to be, and "it was decided that, as the Germans were pressing on, the Belgians must take up the position on the Yser from which the Germans were never able to drive them."

As to the Royal Naval Division, Brigr.-Gen. Edmonds writes: "The wonder is, not that they failed to accomplish what was hoped, but that they fought so well. Had it not been for the unfortunate mistake in the delivery of a message for the 1st Naval Brigade to one of its battalions, and the report that it had been duly acted on, the whole Division would, no doubt, have got clear, for the Belgian 2nd Division easily did so."

The verdict of the Official Historian on Antwerp is as follows: "the continued resistance of the garrison for several days after the bombardment had rendered the outer forts untenable, had a lasting influence on the operations. Had Maubeuge held out only a few hours longer, the German VII Reserve Corps could not have been on the Aisne to stop the advance of Haig's Corps. Until Antwerp had fallen the troops of the investing force were not available to move forward on Ypres and the coast; and though, when they did, they secured Zeebrugge and Ostend without a struggle, they were too late to secure Nieuport and Dunkirk and turn the northern flank of the Allies, as intended. Further, since General von Beseler's divisions (from Antwerp) were required to cover

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the approach march of the four new German Corps in their advance on Ypres, the whole general movement of the German forces in the north was affected. We have seen that on the 7th October, Beseler received a reminder to accelerate matters (at Antwerp). The advantage of a day, nay even a few hours, in the advance of the Germans on Ypres, or an equal delay in the arrival of the French and British re-inforcements, might, as will be seen, have tipped the scale to the enemy's side. Had events turned out more favourably for the main Allied armies in the first week of October, the defence of Antwerp might have proved decisive."

Battles of Ypres. The situation in the north has already been given, and it is important to see what were Gen. Joffre's intentions on that critical date :—The First, Third, Fourth, Fifth and Sixth French Armies were generally to hold their positions, in that order from the right, but to maintain an offensive attitude. The Second and Tenth Armies, under the direction of General Foch, were to continue the action they had begun against the right flank of the enemy in the " Race to the Sea." Should they fail to drive him back, they were in any case to check his advance and prevent him from withdrawing any troops from their front.

" The B.E.F. was to assist in the action of the Tenth Army (General Maud'huy), and it was hoped that the Belgian Army would also be able to co-operate (from the direction of Antwerp)."

The concentration of the B.E.F. on the north was covered by the French XXI Corps, which, by the 8th October, had extended the main battle line to Vermelles, only four miles short of the La Bassée Canal, and further north by Conneau's and de Mitry's Cavalry Corps. These, with one brigade of the 87th Territorial Division and a Chasseur Battalion, by October 9th held a line Bethune-Estaires-Merville-Aire, bending round to the north of St. Omer through the Forest of Clairmarais. Thence the other brigade of the 87th Territorial Division carried it northward to connect with the defences of Dunkirk. Cassel, in advance of the general line, and Lille, were still held by French Cavalry and local Territorial troops.

On October 10th, at a conference at Doullers, between Sir John French and General Foch, it was agreed that the French and British troops in the north should endeavour to make a combined advance eastward, the B.E.F. passing to the north of Lille. The enemy's cavalry appeared to be falling back and there seemed to be every prospect of an easy advance.

To show how close a thing the " Race to the Sea " was, the German XIV Corps had come up opposite the XXI French Corps on October 9th, only 24 hours after the latter was in position to Vermelles. The German I and II Cavalry Corps (4 cavalry divisions) were thus freed and had at once been sent further north to break through between La Bassée and Armentières, and turn the Allied flank. They were checked by the French Cavalry, but the German IV Cavalry Corps, moving independently, had actually passed through Ypres on October 7th, and were only checked by local French Territorial troops near Hazebruck, when they fell back on Bailleul.

General Foch's position up to October 10th was " *délégué du général en chef*," but on October 11th he was appointed Commander of the

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Northern group of armies (G.A.N.). Possibly the news of the fall of Antwerp on October 10th had induced General Joffre to give more attention to the question of co-operation. The effect of the appointment was immediate and made itself felt throughout the heavy fighting which ensued. " The most important point in these first days' fighting in Flanders was the establishment of that close liaison with the French which was to have such wonderful results . . . . even before the great welding of the two armies later in the month in the long and fiery ordeal of the Battles of Ypres." Incidentally, it was during this period that the French word " barrage " came into use as a term to describe the support of the infantry attack by covering fire. The fact that a French word was used tended to conceal the origin of this mode of using artillery fire in bursts to facilitate the infantry advance, which was undoubtedly English, and based on *Field Artillery Training*, April, 1914, pp. 155-7, but with the difference that no one then contemplated an ammunition supply which would enable fire to be continued without intermission for long periods of time.

Thanks to the admirable co-operation of the French, as each British Corps of the B.E.F. came up in échelon on the left, the Allied line was formed with French Cavalry Corps in the intervals. Pivoting on the French on its right at Vermelles, the line swung forward, until the extreme left nearly reached the defences of Lille, while the British Cavalry secured the Messines and Wytschalte ridges and connected with the 3rd Cavalry Brigade of General Rawlinson's force, which had fallen back from Bruges to cover Ypres, and thence through the British 7th Division, with the Belgian Army and French troops along the Yser.

All efforts, however, to advance beyond this line failed, for simultaneously the Germans also transferred troops to the north, and, after Antwerp had fallen, brought up not only the troops released from the siege, but four newly organised " Reserve " Corps which they hurried forward to turn the Allied flank and reach the Channel ports which was their objective. The occupation of Lille and capture of its garrison of 4,000 French Territorials marks the beginning of the stalemate, for it enabled the Germans to hold the line of the Lys facing north-west, and prevented the British Cavalry advancing and turning the German flank. Later the advance of Rawlinson's IVth Corps, with De Mitry's Cavalry Corps on its left towards Roulers was similarly frustrated by the extension of the German line.

This extension of the line resulted in a series of encounter battles, in which the operations were the outcome of a definite plan of attack by each belligerent in turn against the northern flank of his opponent. Brigr.-Gen. Edmonds quotes General Gallieni, who says: " the Allies were always 24 hours and an Army Corps behind the enemy, sometimes more." This was only true in so far that had the Allies had the extra 24 hours and the extra troops in hand, the victory would have been decisive for them. They were not too late to stem the tide of the German advance. In view of the German superiority in numbers the Allies did more than well, and probably the only soldiers who experienced disappointment at the result were General Joffre and Sir John French, whose persistent optimism received a rude blow. It was only the tenacity

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of all the Allied forces in the fighting line that frustrated the Germans reaching the Channel ports, for reserves there were none. Brigr.-Gen. Edmonds again refers to the subject of unity of command on p. 127, when describing the first phase of the Battles of Ypres, October 19th-21st : " There were troops of three nations defending Flanders. Nominally, General Foch had no command over the Belgian and British Armies, and officially he could do no more than forward to their commanders copies of the orders issued to his own troops, and make suggestions for co-operation. As a matter of fact his influence was considerable ; and his proposals, so far as means allowed, were carried out by the Allied Armies, without waste of time and without friction of any kind. French and Belgian, and French and British, as circumstances required, and as far as difference of training, war material and language permitted, fought side by side and sometimes as an army."

The results of this comradeship of early days were far-reaching ; and, in the reviewer's own experience later on in 1915 at Ypres, and in 1918, south of Amiens, the knowledge which the French had gained of British character in the 1914 fighting made co-operation very simple and at once established mutual confidence. The name of General Hély d'Oissel, who commanded the French 7th Cavalry Division in 1914, and afterwards the French Corps north of Boesinghe, is well known to many British officers, but there were many others. He was only one of many distinguished French Officers who were quick to understand the British character, and it was 1914 that enabled them to do it, for they knew little or nothing of England or the British soldier before the war.

On October 11th General Foch's idea was that the B.E.F. should advance eastwards north of Lille to outflank the enemy. On October 18th he still hoped that the Allied forces could move forward from Ypres-Nieuport towards Roulers-Thourout-Ghistelles (5 miles south of Ostend) in order to break the enemy's front, and separate Gen. von Beseler's III Reserve Corps (from Antwerp), which had followed up the Belgians, from the enemy's main forces. " This accomplished, the Belgian Army and the French left were to endeavour to drive Beseler against the coast, whilst the rest of the French Army in the north, with the British, were to wheel south-east, in the direction of the Lys from Menin to Ghent (30 miles north-east of Menin), force the passage of this river, and attack the main German forces in flank and in reverse. It was never possible to put this plan into execution, but it forms the clue to the general operations of the Allies in the north." The Belgians were, however, too exhausted, and the enemy had the advantage, both of initiative and numbers. The French and British forces brought up for the offensive had to be thrust in piecemeal, as they arrived at Ypres, to maintain the front against the heavy German attacks.

" Though the offensive remained the guiding principle it was the German, not the Allied, attacks which marked the different phases of the battle. The first British and French attacks led to a ' battle of encounter,' and then the Allies were thrown on the defensive."

The German plan was the exact converse of that of the Allies. Then, " Failing to break in north of Ypres against the Belgians, the enemy

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made desperate attempts against the British, first east and then south-east of Ypres, until the battle died away."

" The German General Staff for a time asserted that the first battle of Ypres was a German victory, for it marked the 'failure of the enemy's intention to fall on the rear of our Western Armies, to free the rich districts of Northern France and the whole of Belgium,' but it is now admitted that it was a failure, to which the subsequent difficult position of Germany must to a great extent be attributed."

The narrative of the fighting must be left to the reader. It is extremely clear, and the maps are excellent, showing the situation from day to day.

Brigr.-Gen. Edmonds has something of interest to say on the employment of the British Artillery (p. 164) and a good deal on the lack of ammunition (pp. 164 and 203 and many other places). On p. 154 he remarks on the curious fate by which " the German and British Cavalry instead of being in reserve, where their mobility might have been of value, were both enmeshed as connecting links in a trench system." He emphasizes the value of the musketry training which enabled two British Cavalry Divisions to preserve an unbroken front against the attacks of six German Cavalry Divisions on the Messines-Hollebeke section of the front. The French Cavalry were so badly armed that they were greatly handicapped in this respect.

Naturally, he has a tender feeling for the magnificent resistance of the 4th Division of the IIIrd Corps (General Pulteney) in front of Armentières, where, on October 24th, that Division held a front of 8 miles, opposed by a force of double its strength. "The 4th Division was left with the impression that by straight shooting over the parapet, backed up by a crossfire of artillery and flanking fire of machine guns, it could stop a German attack of almost any weight. The action of the divisional artillery, then commanded by Brigr.-Gen. (now General) G. F. Milne, was extraordinarily effective," but it always somehow managed to keep one of its four brigades out of the line for rest. This was easier, of course, when ammunition was scarce, for some days it was limited to 40 rounds per 18-pdr., and 20 per 4.5inch howitzer. This was doubled on 1st November. The casualties of the IIIrd Corps between October 15th and 31st, were 207 officers and 5,572 o.r., of which 125 officers and 3,585 o.r. were incurred in the other division (6th) of the Corps and Corps units. It is of interest to R.E. that a distinguished officer of the Corps, Brigr.-Gen. Hunter-Weston, commanded the 11th Infantry Brigade of the 4th Division during all this fighting.

The reader must, on no account, omit to read the notes though they are in small type. In them are concealed some of the most interesting information in a volume where everything must be of value to the soldier student. For instance, at the end of one of these " Notes," p. 259, there is the brief statement that while at Ypres the British heavy artillery consisted of only two batteries of old 6-in. howitzers, two batteries of 4.7-in. guns, and one naval armoured train with one 6-in. and one 4-in. gun—18 guns in all, or 26 including the 60-pounders, the heavy artillery of Fabeck's Army Group for the break-through at Gheluvelt was 8 batteries of mortars, 60 batteries of heavy field howitzers and a 12-in. "coast defence mortar," over 250 heavy guns in all.

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In another note, p. 261, the difficulties of motor transport on the narrow Belgian *pavé* roads are described, and how the British gradually came to ignore the French cut and dried method of "fixed circuits," and directed the traffic regardless of the circuits, with the tacit consent of the French themselves—one of the many instances where the French inherent love of the theoretical and logical was up against the British "flair" for the practical and perforce succumbed to it.

There are frequent references to the R.E. On p. 176, for instance, "The engineer field companies worked on defences when shelling permitted, but the sappers were often called upon to take up their rifles to form a reserve, to assist in repelling the enemy, and even to join in attacks." In this connection, the action is described—in a footnote on p. 187—of Major H. L. Pritchard and the 26th Field Company at Langemarck on 23rd October; the counter-attack in which the 5th Field Company lost its Commander, Major A. H. Tyler, 2 other officers and a quarter of its men, killed, at Nonne Bosche, on November 11th (vide also *R.E.J.*, October, 1919, p. 179); the sacrifice of the 20th and 21st Companies of Sappers and Miners in the counter-attack at Neuve Chapelle on October 28th. As to the latter a footnote is worth quoting—"The use of the engineer companies as 'storm troops' in a situation that was not desperate, was a mistake. It crippled the Lahore Division for a considerable period, and . . . was ascribed to ignorance of Indian organization. But elsewhere in 1914 engineer troops were employed without a due sense of their technical value, and it became necessary for Sir John French to issue a memorandum calling attention to the misuse and waste of highly skilled specialists in work that should be performed by infantry."

In still another footnote, on p. 204, Brigr.-Gen. Edmonds directs attention to what was one of the most striking features of German tactics throughout the war, namely that "every opportunity of seizing important points on their immediate front," must be taken. Time after time, one found the Germans in possession of some point on the front, where either facility for observation or its inherent tactical value made it a thorn in the side (or rather front) of our troops. On p. 220 he refers to "their (the Germans') characteristic probing for a weak spot. The combination of the two, the probing for a weak spot in their attacks, and the prompt recognition and seizure of important tactical points went a long way to counterbalance what he describes on another page as the failure of the rank and file to follow up a successful attack: "Time after time during the battles of Ypres the same phenomenon will be observed: the Germans having come on in overwhelming numbers and succeeded in penetrating our line, sat or stood about helplessly and without precaution. Either they were content to rest after reaching the objective that they had been given, or they did not know what to do next. In any case, whether units of the Regular Army or newly raised Reserve formations, they usually fell an easy prey to the British counter-attacks." The same tendency has been noticed by the Germans in regard to the divisions of the British New Armies, *e.g.*, at the battle of Loos (footnote p. 199).

Almost the most valuable portion of the book is the Retrospect, pp. 460-5, which no reader must miss. One statement in it gives much food

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for thought :—" That British troops have fought comparatively few successful offensive battles is due mainly to their commanders never having at their disposal forces adequate for such a purpose. Yet Minden, Blenheim, Salamanca, and Vittoria had shown what they were capable of in attack, and the counter-attacks at Ypres were not only crowned with success, but had truly marvellous results. . . . . When the opposing sides are of nearly equal value in training, courage and experience, and equally well commanded, decisive success can only be obtained—given even the advantages of surprise and preponderance of material—by superior numbers. The Germans had a numerical superiority of nearly two to one in their favour on the Ypres front as a whole, and far more favourable odds in particular sectors, but it did not avail them for inferior leading and other factors."

To conclude :—

The following extract from a letter is not printed in this volume.

" The Autumn of 1914, saw the Old Army for the last time. Everyone knew their parts, and acted and did not wait for orders; all were accustomed to work with other arms. Everyone was fully trained in the use of his weapon. The New Armies never knew the Old Army, for it was dead before they came into existence. The Officers and Men who filled up the New Armies' ranks were never fully trained; the staff was diluted and doubled, so that the all-round staff officer ceased to exist and was replaced by a number of specialists."

That the Old Army died in 1914 is borne out by the figures given on p. 467 :—

The grand total of losses from the commencement of the campaign was :—

	Officers.	Other Ranks.
Killed	842	8631
Wounded	2097	37264
Missing	688	40342
	3627	86237

The greater part of this loss had fallen on the infantry of the first seven divisions, which originally numbered 84,000. The reinforcements sent out, apart from new formations, were :—962 officers, 108,610 other ranks.

The German losses in the three battles, of Lille, the Yser, and Ypres, from 15th October to 24th November, were 3,015 officers and 131,300 other ranks, which apparently excludes the wastage during the period in formations not actually engaged in the battle areas. But Brigr.-Gen. Edmonds does not think that there is much to be learned by a comparison of the figures, as the British and German methods of recording casualties differed.

It only remains to be said that there are two excellent Indices, a General Index, and an Index to Arms, Formations, and Units. The 40 maps are in a separate case, and are uniformly good and clear; but it is quite possible to read the volume, though not with a view to deep study, with the aid of the maps and "sketches" included in the letterpress.

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The Appendices include the " Order of Battle " of the British (including Indian Corps), French, and German Armies, and most of the important orders are given in full.

H. BRUCE WILLIAMS, *Maior-General* (retd.), late R.E.

LA GRANDE GUERRE SUR LE FRONT OCCIDENTAL.

Vol. X. La Ruée sur Verdun (5 août 1915-30 juin 1916). By GENERAL PALAT. (Paris: Berger-Levrault) 25 francs.

THE previous volumes on the great war by General Palat, well known before 1914 as a writer, under the name of Pierre Lehautcourt, on the war of 1870-1, have not been reviewed in the *R.E. Journal*. Whilst the French official account, which has only reached 23rd August, 1914, is mainly a reprint of documents, General Palat's work is not well *documenté:* he relies on books and pamphlets that have appeared, private diaries and notes lent to him, and the assistance of very numerous friends, mostly in the higher ranks, who took part. With each new volume he publishes corrections received of his former ones. In general, therefore, his book, although it has not the authority of an official work, and although it has some gaps in the narrative, is a most useful summary, full of details not likely to be given in the official history. In the present volume on the opening phases of the German attack at Verdun, which is of special interest to engineers, there is already such a mass of printed official and unofficial matter, that, except in the matter of operation orders, his account is very complete. It is unfortunately lacking in good maps, for only portions of the 1/50,000 and 1/80,000 maps, without any troops or trench lines marked on them, are provided; but at the low price of the book this must be expected. There is a small plan of the underworks of Fort Vaux.

General Palat takes up a somewhat critical attitude as regards the Commander-in-Chief and the operation staff. In 1914, during the great retreat to the Seine, although French G.Q.G. had ordered the field Armies to retire past Verdun, General Sarrail, commanding the Third Army, had clung to it with his right flank, and thus had formed the eastern side of the bag—Paris and Galliéni's troops being the western—into which the Germans thrust themselves on the eve of the battle of the Marne. Henceforward Verdun formed a salient in the general front, a salient dangerously narrowed on the east by the Germans' lucky thrust to St. Mihiel during the retreat.

French fortresses were specially protected by law and could not legally be declassed without what we call an Act of Parliament; their commanders were responsible to the Government for the safe-guarding of their trust, and were independent of any commander-in-chief. On 5th August, 1915, General Joffre, who badly wanted the heavy artillery locked up in Verdun, managed to get the place secretly declassed as a fortress by a decree of the Executive, and converted into the *Région Fortifiée de Verdun* (R.F.V.), and an integral part of the field Army; and he superseded the Governor by a corps commander, General Herr. Then he set about despoiling the fortress of its men, its guns, its ammunition and its stores, and bled it white to feed the battles in Champagne:

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> " A fort as important as that of Douaumont was left without even a security garrison, without mobile *materiel*, without ammunition, and, by inexcusable blindness, without even guns to flank its ditches."

The strong, carefully chosen line of defence, the forts, was abandoned for a trench line in front, far less strong.

> " It is natural that the commander-in-chief desired to have more direct power over the fortresses in the zone of the Armies. To go beyond that and destroy an existing organization, like that of a great fortress, without being certain of the power of reconstructing a substitute, was an imprudence difficult to justify."

The author is inclined to attribute the course taken "to the false ideas, or rather the lack of ideas," in the General Staff as to the rôle of fortresses. To prepare the new line General Herr had neither men nor *materiel*.

The state of the defensive line near Verdun became so notorious in the army that Colonel Driant, a member of the Chamber of Deputies, who was serving in the " Region," informed the Standing Committee on the Army. There was much talk, but little done; for Joffre would brook no interference, and when the German attack came, the first position, which consisted of three lines, not continuous, but organized as a series of strong points, was incomplete as regards wire and practically without shell-proof cover. There were concrete shelters for machine guns in the 2nd and 3rd lines, but none in the first. The second, third and fourth positions had been laid out in 1914, according to the ideas of that time—half a metre wide trenches, nearly straight, with metre traverses and plain wire. They had not been kept up, and, except the fourth, were hardly fightable in 1916.

One of the great weaknesses of Verdun was the insufficiency of its communications with the interior of France. Owing to the position of the enemy round the fortress, it was only served by a single metre gauge railway; of the two broad gauge railways that ran to it in peace time, one was in the hands of the enemy, and the other under his fire. Finally, as if to complete the confusion in the organization, on 30th January, 1916, three weeks before the German attack, the *Région Fortifiée de Verdun* was transferred from the Group of Armies of General Dubail (East) to that of General de Langle de Cary (Centre).

The fighting is described at considerable length. Bad weather, which prevented the Germans from moving their guns forward after the first phase, probably saved the French from the loss of Verdun in the spring. But General Palat considers the most important factor was that the German 16-in. howitzers were marked down by artillery experts and knocked out by French long-range guns (155 and 100 mm.), " Long Tom had the better of Fat Bertha," and that the great German artillery dump of 450,000 heavy calibre shell was blown up, thanks to the Germans keeping their shell fuzed.

There is a very interesting report by General de Grandprey, a distinguished officer of engineers, on the resistance of permanent fortifications to modern heavy artillery, and what he says can be verified by the casual visitor, for Thos. Cook & Sons' tour of Verdun includes a long visit to Fort Vaux, which, with Douaumont, suffered the heaviest

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and longest bombardments. Nothing built before 1885—this would include most of Antwerp—was of any use. A layer of 2.50 metres of good concrete, or 1.75 metres of reinforced concrete, as we already knew, was not pierced by the heaviest shell. The whole of the casemates, passages and under works of Vaux are intact; at Douaumont, where there was an internal explosion during the German occupation, owing to the accidental ignition of some hand-grenades, five casemates only are unfit for occupation; the remaining 13 upper ones and the whole of the basement ones are intact. Large masses of concrete, and large steel shields resisted well; small buildings, and the small shields of machine-gun emplacements were of little use. There is no detailed description of the concrete; nor is the method of ventilation touched on.

Though not a technical engineer study, the book as showing the resisting power of a well-fought fortress is of considerable interest, and is the most compact account of Verdun that is available.

J.E.E.

SIR JOHN MOORE'S SYSTEM OF TRAINING.

By COLONEL F. J. C. FULLER, D.S.O. (London: Hutchinson & Co.) 10/6. Illustrated.

IN a smaller work on "Training the soldier for war," published in 1914, the author referred to Sir John Moore's system, based on intimacy between Officers and men, and not on familiarity, on self-respect and not fear, which produced a body of men—the renowned Light Division—unsurpassed in war. He has now collected together many details of that system, which was so soon to prove its worth that it cannot fail to command the attention of all students of military matters. We can readily accept Seaton's assertion that the foundation of Wellington's successes was laid at Shorncliffe.

Moore was a believer in what we are pleased to call the human touch, as distinct from the then more universal but brutal methods of Frederick the Great. We are given a short account of his life, in which we could find no mention of the fact that he was once a Member of Parliament. "*De Mortuis . . !*"

Interesting *résumés* are given of the existing regulations and orders regarding training and organization. These are followed by the principles which Moore observed and the ideals to which he pointed, as exemplified in the standing orders of the units of his Brigade. The numerous extracts contain much to think about and much to smile over, and make it abundantly clear that military progress is merely cyclical. For example, here is the gist of a recent Army Order, but dated 1800: "Every Sergeant is expected to be master of reading, writing and the first four rules of arithmetic," and here is Recreational training and amateur status in a nutshell: "The Captains and other Officers are requested to show every encouragement to their men to amuse themselves at the game of cricket, hand or foot ball, leap-frog, quoits, vaulting, running, foot races, etc.; money is never to come in question as a prize, but any other descriptions of premium which can be thought of." "All soldiers should be able to cook. To doom one soldier to perpetual cooking is wrong, no

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man worthy to bear arms should be degraded to the office of perpetual scullion for his comrades." (Cf. Courses of Instruction, 1925).

They held downright opinions in those days, and even dared to express them. We read that one Colonel Hanger addressed himself to Lord Castlereagh as follows: " I hold in detestation and abhorrence all *Button* and *Buckle* Officers, and I never yet have seen a real *Martinet* or a *tip-top Adjutant* (excuse, my Lord, the vulgarity of the latter expression) ever turn out a good soldier on service; . . . . their ideas soar no higher than pipe-clay, buttons, lacquering of caps, the precise length of the pigtail, even to the quarter of an inch."

Knowing our" Reformation of War " we half hoped for a little futurism. Would death-rays (on both sides) have affected the issue at Sahagun? What if the concentration at Boulogne had been one of televisionaries? And supposing Castlereagh, busy penning Moore's appointment to the Chief Command in Spain, had fumbled with his face-piece (for all proper wars start with the gassing of Ministers)?

The references, which are mostly to James Moore's " Life," and to Sir J. F. Maurice's " Diary," are complete and accurate, so that the context of the many quotations is easily found. This is Sir William Napier's opinion of Moore's system: " The Officers were never averse to being made to acquire, amidst the private soldiers, a complete knowledge of what, as officers, they were to exact from, and superintend with, those privates. Never did the system lead to disrespect or undue familiarity on the part of the soldiers; on the contrary, it produced the natural effect of knowledge combined with power, willing and entire obedience from the soldiers, while the officers were proud of their acquirements, knew their men and were known to them; knew when to exact and when to relax, and were in every sense commanders."

I.S.O.P.

MILITARY ENGINEERING.

(TECHNICAL TRAINING. Vol. II. ELECTRICAL ENGINEERING. 1924.)

" WHAT knowledge should an engineer have in his head and what knowledge should he have in his books? " That is a question which every one has to consider who has to do with the training of engineers. The question is not of such vital importance to an engineer stationed in England, where he can surround himself by an unlimited number of books, and moreover has more or less frequent access to the best stocked libraries and where the telephone can put him into instant communication with any expert on any subject. It is a much more important problem for the sapper officer or civilian engineer working overseas and having to rely on his own knowledge and commonsense and on a small collection of text books strictly limited by transport considerations.

Both the military and the civilian electrical engineer thus situated, would be better served by a Molesworth and the book under review than by a whole shelf full of other books. The second part of the above question can, therefore, be answered since the appearance of this publication. It is not possible to anticipate every engineering problem someone may be up against at some future date, and in an unknown

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place and faced with an unforeseen situation; but the anonymous editor and authors have shown themselves to possess just the kind of imagination that enables them to picture the sort of information a sapper officer is likely to require, and to supply that information in a form that is both clear and inspires confidence. The book covers all the electrical engineering ground that may, in the ordinary way, come within the scope of a sapper officer's activities.

If he has to design an electric generating station, he will find facts and figures to help him to decide on the size and type of plant, the type of current, the voltage, the best site for his station. Full descriptions of existing military stations will guide him on orthodox and proven lines. He is told what switch gear is required in various cases, what he may need in the way of transformers and how to instal them and phase them out, what protective gear is required, and he is advised on earthing, with an emphasis which is very welcome, considering how often this subject is carelessly treated.

For those whose problem is mainly one of transmission and distribution, methods for calculating cross sections and voltage drops on both H.T. and L.T. systems are given. The method given for calculating complicated L.T. networks is not the neatest possible one, but, for the purposes of the book it is the most serviceable, as it involves nothing more abstruse than simple arithmetic and it is easy to understand. The D.C. three-wire and the A.C. three and four wire systems are explained, and their economies over two wire systems worked out. The A.C. six-phase system now coming into favour might, with advantage, be included in future editions. Cables are very fully dealt with from the points of view of choice of type and size, manufacture, laying, jointing and testing. Design, calculation and erection of overhead lines are given an amount of space proportional to their importance in military work.

So far the first part of the book. The second part is devoted to the utilisation of electric light and power. Guidance is given as to the necessary intensity of illumination, the proper disposition of lamps and the best type of lamp and reflector for all possible cases of indoor and outdoor lighting. Different methods of indoor wiring are explained and compared, points requiring special attention are emphasised, methods of calculation and most valuable information about fittings are given. All types of electric motors and secondary batteries are dealt with in the same sound and practical way. The characteristics of different motors are explained, together with their field of application. Rating, protection switching arrangements, installation, are all discussed.

One hundred and eight plates at the end of the book give a variety of pictorial information. There are typical station load curves, model diagrams of connections for a number of circuits, drawings and photographs of all kinds of electrical gear, pictures of indoor wiring and overhead line work. The plates are well selected to impart a maximum of knowledge, while avoiding redundancy. At the end of each chapter a bibliography is given. Official regulations and B.E.S.A. standards are quoted wherever they are relevant to the subject matter.

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So much for the ground covered. The kind of knowledge conveyed is concerned with the type of machinery, apparatus or material required for a given purpose and the basis on which to decide between available alternatives; the way to determine the size and capacity of the individual parts of an installation; the cross section and voltage drop of transmission lines; design of buildings; care of batteries; the dimensions and weight of individual articles, and where these are obtainable through official channels, the rather mysteriously worded official designation, and frequently, though perhaps not as frequently as one might wish, the cost of articles. In short, the book gives guidance as to what to instal, how to instal it, what it looks like, where to get it, what it costs, what it does, how to look after it. Such questions as maintenance, log sheets, diagnosis and repair of breakdowns receive less space than one might expect. The index is carefully worked out, but errs perhaps on the side of economy. A great deal of information is given in the form of tables.

In a short summary like the above, it is not possible to convey an impression of the large amount of detailed information contained in this publication. The editor's sense of proportion in assigning to each subject just about the amount of attention and emphasis justified by its probable importance in the work of the Royal Engineers deserves special comment. The authors have managed to make the book more up-to-date than one might have thought possible, considering the inevitable lapse of time between compilation and publication. It is inevitable that some of the most recent practice cannot always be included, such as the saving with the use of transformers with tappings on static condenser installations for stepping up to the highest voltage the condensers can stand, or the employment of Maconite cable for indoor wiring.

On the whole admirable thought has been devoted to ensuring that every statement shall be accepted practice, strictly relevant, comprehensible and helpful. The book aims at giving clear cut facts and opinions; something as definite as possible for the reader to work to. This method has the defects of its virtues. Engineering facts cannot always be accurately put in quite such unqualified terms as found here. But what the user of the book needs above all things, is positive guidance. Too many "buts" and "ifs," too many qualifications and niceties would unsettle him. The authors, therefore, have wisely contented themselves with giving facts and figures which are broadly true for the conditions likely to arise in military work, even though they may be open to doubt for other conditions. Thus it is broadly true within the range of size of military stations to say that 11 pounds of steam per k.w. hour is the absolute minimum steam consumption of turbines, although this figure can be improved on with high steam pressures, large sized units or exceptionally cold circulating water. The rule that a generating station should be at the centre of gravity of the load for maximum economy applies where voltage drop determines the cross section of transmission lines, as is usual for military systems. Where heating of conductors is the limiting factor this rule does not apply by any means. In all such cases the authors' method of giving information in quite definite terms, though a simple definite statement cannot possibly be a completely

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accurate one, seems to be perfectly justifiable and greatly preferable to the alternative of confusing the reader by a lengthy dissertation on limiting conditions and the factors involved in the problem. The extra information conveyed in this way would be rarely, if ever, required by the reader. Considering how many factors influence anything in engineering and how difficult it is to say anything that is strictly true without limitations or qualifications, the authors have shown remarkable skill in getting down just such facts and figures as can be safely expressed in definite terms without marked scientific inaccuracy.

All this shows that the book under review is a thoroughly practical one in the best sense of the word. That blessed word " practical " has come to be so thoroughly abused that one hesitates to use it. We all know the self-styled practical engineer. He knows next to nothing, thinks very little, but is generally good at keeping a motor car in perfect repair. Anything he cannot understand he dismisses a little contemptuously as theoretical. Hence a great many things appear to him theoretical. Such a man will not find the book under review conspicuously practical. For one thing it contains too many quantitative statements, and the self-styled practical man prefers his books to combine a maximum of description with a minimum of information.

The engineer, on the other hand, who is out to get the best job done, the one who wishes to obtain a maximum of reliability, simplicity, economy and efficiency, will find in this book those facts which are most relevant to his problems. He can rest assured that even if the why and wherefore are not always told, the authors have based their statements on principles that are sound theoretically, as well as practically. Nevertheless, he will not be able to make full use of the book unless he has had a sound previous training embodying a certain amount of theory. Without this he may come to rely too much on the printed word, particularly when the printed word appears so definite, and too little on first principles. He may fail to realise that engineering is a living craft and that the last word has not yet been said on any of its subjects. He may miss important things in the book, not because they are not expressed in terms that he can understand, but because it is not easy to appreciate the full import of every statement in a condensed piece of writing unless one is prepared for it by one's general knowledge of the subject.

We can now give some sort of an answer to the first part of the question formulated at the beginning of this review. What the engineer should have in his head is at least an understanding of the why and wherefore of things. Thus equipped mentally, and armed with the book under review, he need not fear to tackle most electrical engineering jobs the sapper officer is likely to be faced with at home or abroad.

REGINALD O. KAPP, B.Sc., Chartered Electrical Engineer.

MILITARY GEOGRAPHY OF THE BRITISH COMMONWEALTH.

By MAJOR A. E. W. SALT, B.A. (Balliol College, Oxford), M.A. (McGill University), Army Educational Corps. (Gale & Polden, Ltd.) Price 10/-

THE choice of books for study is the first care of an Officer about to work either for a Promotion Examination or for the Staff College. For some

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subjects he finds himself hard put to it to lay hands on the book which will give him the information that he wants. This is not the case with Military Geography. With this subject his difficulty is rather to select the one or two books which will best suit his requirements from the galaxy of works which are now available.

Any new book on this subject must, therefore, be a star of some magnitude to command attention.

The ground covered by Major Salt's book includes all the geographical matter required for examination purposes, and the book contains a lot of very useful information.

The first chapter deals with the history of the development of the British Commonwealth; but it is hardly possible to condense this history into fifty pages, and still to retain a form in which it can be read and remembered.

It is, therefore, mainly from the geographical point of view that the book must be considered. Under this heading accuracy of detail is of the first importance. Here Major Salt's book fails badly.

On the subject of India we read that "British troops are organised into Brigades and Divisions with the Indian Army, the normal proportion being 3 British Battalions to 1 Native." This is probably only a slip; but confidence is not restored when we find "it is so intensely hot in the plains in the summer that Europeans have to retire to Simla, Darjeeling and Poona in the hills."

We turned to Canada feeling that the author's connection with McGill University justified the hope of accuracy here at least. Comparison with the Canada Year Book 1922-23, however, showed a whole series of discrepancies. The population of Toronto is given as 377,000, whereas in 1921 it was 521,000 odd. Similarly Hamilton 82,000 instead of 114,000; Winnipeg 137,000 instead if 179,000.

Other figures were no more correct. The number of Chinese and Japanese in Canada are given as 27,000 and 6,000, respectively. The figures of the 1921 census are 39,000 and 16,000.

Nor can the inaccuracies on Canada be confined to figures, for to say that all over Canada "except in British Columbia and in the Maritime Provinces . . . . the thermometer stands always below freezing point from November to April" is sheer nonsense.

The book really needs careful revision before it can be recommended to Officers working for examinations. When it is revised it is to be hoped that an index will be added. Without one a book of this type loses much of its value.

R.H.D.

THE HISTORY OF THE TELEPHONE IN THE UNITED KINGDOM.

By F. G. C. BALDWIN, M.I.E.E. (Chapman & Hall, Ltd., 42/- net).

It is now nearly half-a-century ago that the general public in this country first had the opportunity of making practical acquaintance with the telephone as an instrument possessing commercial value. Towards the end of the 70's of the last century, an Exhibition was held at the

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Crystal Palace and there among the novelties then shown was the then recently invented Bell telephone. Within the great building, two primitive call-boxes, which were roofless, had been erected a few hundred feet apart and a wire had been run between these two structures, each end of which was equipped with a single hand telephone. Those were days before Hughes had announced his discovery of the microphone, and consequently apparatus which to-day does duty as "receiver" only had to do the double duty of "transmitter" and "receiver," being held alternately before the mouth and at an ear to enable a conversation to be carried on. At the Exhibition a charge of 1/- a call was made to those who desired personally to test the efficiency of this new means of communication. There were no secrets to be told over this circuit, so that the designers of the call-boxes were not called upon to make an attempt to construct them as "soundproof" cabinets, nor did they do so; in consequence, a number of persons (mostly schoolboys) who were either unwilling to risk a shilling on a telephone talk which might come off or might not, or perhaps hadn't this sum to spare, were able to look down from one of the galleries (parallel to which lay the telephone circuit) and watch the proceedings in the call-boxes and listen to the words spoken at one end of the line. Many of those who entered the call-boxes were either shy and nervous or were overcome with awe in the presence of the uncanny apparatus with which they were closeted; anyhow, they became bereft of speech and could not proceed beyond the preliminary hailing words: "Hello! Hello! Are you there?" Since those days, improved telephones have invaded the county-house, the workshop, our homes and our public places and they have no terrors either for the very young or the very old, and to-day, either from the most public places in our great cities, or from a comfortable chair in an office, or a home, any one desiring to do so can, for a charge calculated in many cases in pence only, carry out, by means of the telephone, without any fear of being overheard by mischievous eaves-droppers, most important transactions requiring the utmost secrecy, and that with a correspondent many hundreds of miles away. In the volume under review, which is excellently illustrated, its author describes in considerable detail the successive stages by which the telephone and its simple circuit of half-a-century ago has been gradually improved and perfected so as to provide the elaborate telephone systems which are utilised to-day by millions of people resident in widely-separated localities daily to settle thousands of far-reaching business transactions with certainty and rapidity, and also in comfort to fix up in a few moments thousands of social engagements on the spur of the moment, so to say.

Mr. Frank Gill, Past President I.E.E., formerly Engineer-in-Chief of the late National Telephone Company, has kindly contributed a "Foreword;" in the last paragraph thereof; he says: "There is much in this book of great interest, but I think it has, to the student of social history, a value even greater than to the student of telephony"; such undoubtedly is the case. The details which are given in the volume of various types of apparatus, of the different circuit arrangements and of the process of evolution which has been continuously going on since the telephone took practical shape, and is still continuing, are necessarily

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very technical, and, therefore, are likely to appeal alone to the student of telephony; on the other hand, there are many other aspects of the history of the telephone, particularly those which affect its introduction and exploitation in this country, which cannot fail to excite the interest of a very wide circle of readers; such is likely to be the case, *inter alia*, in the parts of the volume which tell the story of the many vicissitudes through which the telephone has passed in this country owing to the vacillating policy of the General Post Office; the great law suit, the Attorney-General v. The Edison Telephone Company of London, in which the Attorney-General, on behalf of the Postmaster-General, successfully argued that the wires and apparatus of the Telephone Company were telegraphs within the meaning of the Telegraph Acts, and that messages and other communications transmitted by means of any such wires and apparatus were telegrams within the meaning of the same Acts, and, consequently, that the operations of the Telephone Company constituted an infringement of the exclusive privilege conferred upon the Postmaster-General by the Telegraph Act of 1869; the imagination of the pioneers who put their faith in the telephone as a weapon of commerce and, undaunted by many and serious obstacles, helped to establish the telephone as a public service; the rivalry of the early telephone companies and the internecine war carried out by them, which really was beneficial neither to themselves nor the telephone users, ending finally in the triumph of the keen and competent business men who succeeded in bringing about the amalgamation of the competing telephone companies and eventually in creating the powerful and highly efficient organisation known as The National Telephone Company, which, after an existence of some 28 years, came to an end on the expiry of its licence on December 31st, 1912, the Government taking over the greater part of its plant and its officers and employés, excepting those in the highest grades; the attempt to establish municipal telephone systems in this country under licence from the Postmaster-General and its failure; and the question of tariffs.

The story of the development of the telephones in the United Kingdom told by Mr. Baldwin is, as might be expected, to a great extent the history of The National Telephone Company, until its plant was taken over by the General Post Office, but the author of the volume has, at the same time, been at great pains to seek out and record information in relation to the work done by Post Office engineers, much of which has been most valuable and of a pioneer order, both prior to and since the acquisition of the National Telephone Company's undertaking by the State; the story of the development of telephone systems has been brought down to date, all recent advances, e.g., the improvements in and introduction into this country of machine-switching equipments and the progress made in telephone repeating devices, resulting in the installation of valve-repeaters on our long distance trunk lines, are duly recorded. The contents of the volume under review constitute a valuable piece of research work into the history of telephony, not only in this country, but also in other parts of the world, and, with the progress of time, the information collected by Mr. Baldwin, particularly that in relation to the original work in the telephone field done in this country,

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cannot but become increasingly interesting and useful, and will give a new starting point to those of a later generation who desire to compile a record of the further progress made in the science and art of telephony. In a work of this kind, and of its dimensions, it is practically impossible, even with the most careful proof-reading, altogether to prevent small errors from creeping in; the author is, therefore, to be congratulated, as the number of errors observed is exceedingly few and not of a kind to mar the value of the volume.

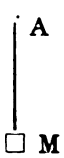
W. A. J. O'M.

THE HODSOCK BALLISTIC TABLES FOR RIFLES.

By F. W. JONES, O.B.E. With an introduction by LIEUT.-COLONEL MELLISH, C.B., V.D., and an Appendix on THE BALLISTIC PENDULUM. By COLONEL LORD COTTISLOE, V.D. (Publishers: Edward Arnold & Co.) Price 10/6.

THESE tables are difference tables, having as their object the facilitation of the calculation of the striking velocity and time of flight of bullets and the elevation of rifles; they have been compiled from experiments made with the ballistic pendulum on the private range of Colonel Mellish, of Hodsock Priory, near Worksop, by the Author and Major, the Hon. T. F. Fremantle, now Lord Cottisloe, in the years 1897-98. The first three chapters of the book, which comprises 80 pages, are devoted mainly to the mathematics of ballistics, the fourth explains an empirical formula for the ballistic constant and the last deals with the practical use of the tables

If a mass M be suspended from a point A vertically above it, and be given a velocity V, it will swing through a certain angle which can be computed, and conversely if the angle of swing is known V can be found.



If a bullet moving with velocity v give such a pendulum of mass M as velocity V, then, by the principle of momentum $mv = (M + m)V$, supposing the bullet to become embedded; now as, m and M are both known and V can be observed, it follows that v can be calculated.

The formula used was

$$v = \frac{M + m}{m} \times \frac{\Pi}{12t} \times a.$$

Where t is the time in seconds of a single swing and a is the horizontal distance moved.

The pendulum used was 132½ inches long, weighing 147 lbs., and consisted of a hollow 6-in. x 6-in. steel bar, 133-in. long, suspended by wires, on to one of the 6-in. x 6-in. ends a hard steel socket, 10-in. dia., was fixed, into which was bolted a 3-in. thick hard wood plug, into which the bullets were fired; the apparatus was protected by a 12-ft. x 12-ft. shield, having an 8-in. circular hole so placed that all bullets passing through the hole would strike the pendulum; for a velocity of 2,800 f.s., and a bullet of 175 grs., the displacement is about 4-in.

Suitable arrangements are provided for recording the motion of the pendulum.

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Experiments have been carried out up to a range of 1,000 yards.

If the velocity of a projectile moving nearly horizontally decrease from v_1 to v_2 (a little less) in passing over a space s, then the average air resistance is $m(v_1^2-v_2^2) \div 2s$. Mr. Jones applied this formulæ to calculate the resistance for specific velocities and space intervals as established by experiment, and the information thus obtained enabled him to deduce the following empiric formulæ for velocities above 1120 f.s. :—

$$R = \frac{1}{12.07474}(v-950)\cdot^7$$

For velocities 1120 to 1040 f.s.

$$R = \frac{1}{46.4186}(v-980)$$

For velocities 1040 to 800 f.s.

$$R = \frac{1}{804.6}v.$$

Given these formulæ, the methods explained in any text book on particle dynamics can be applied to obtain space, time, velocity relations.

The changes of inclination of the tangent to the trajectory in terms of time intervals and velocity, have been calculated from a method devised by the late Professor W. D. Niven, F.R.S., an eminent mathematician ; it is too lengthy to explain in a review.

The tables have been computed for a ballistic coefficient of unity ; to use the tables the proper ballistic coefficient must be applied, this depends on weight and diameter of bullet and on what is termed the "coefficient of form."

It is stated that recent experiments have shown that the ballistic pendulum gives results which very closely agree with those obtained by the much more elaborate chronograph method. The velocities, etc., deducible from the table have been extensively checked by experiment, and the remarkable coincidence is a tribute to the accuracy of the empiric formulæ. The mathematics of the work is simple and clear. I consider the book an admirable one and an instructive exposition of the use of mathematics and experiment in combination.

J. M. WADE, Lieut.-Col., B.SC., London.

30-3-25.

THE ELEMENTS OF MECHANICS.

By F. S. CAREY, M.A., Professor Emeritus in the University of Liverpool ; and J. PROUDMAN, M.A., D.SC., Professor in the University of Liverpool. (Longman, Green & Co., 39, Paternoster Row, E.C. 4.) Price 8/6.

THIS is an elementary work on statics, dynamics and hydrostatics, suitable for advanced classes at schools, and for first year students at universities; its study does not require a knowledge of the calculus. The scope of the treatise is almost precisely the same as that of other elementary works ; it is not and does not purport to be suitable for a complete beginner though the subjects are treated *ab initio*. I may mention that the term " elementary " as applied to mechanics constitutes a domain

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not requiring the calculus or a knowledge of analytic geometry of three dimensions, consequently such subjects as forces, and motion in three dimensions, wrenches, the equilibrium of strings, attractions, and the general theory of rectilinear, orbital and constrained motion are necessarily excluded.

The features of this treatise which differentiate it from others are:

(1) Statics and dynamics are developed side by side.

(2) The theory of vectors is largely used, and two chapters are devoted to their purely mathematical theory.

As to the first of these innovations, there is little doubt that the parallel development of statics and dynamics makes these sciences more interesting and intelligible to the young idea.

With regard to the use of vectors, some teachers will approve, others may not; there are already several excellent works on statics and dynamics, noticeably those by Professor S. L. Loney, of London University, and the authors may have felt that there was no necessity for another treatise on the lines with which all of us are more or less familiar; the importance of vectors is becoming more and more recognised and the book under review is a good illustration of the conciseness and generality gained by their use.

Chapters 22 and 23 contain an elementary, but useful, introduction to rigid dynamics; the inclusion of the elements of this subject in an elementary work is an innovation with which most will agree; though rigid dynamics is much more difficult than particle dynamics, it is, nevertheless, much more interesting and stimulating, and the sooner the student is introduced to this important branch the better. There are but two chapters on hydrostatics; the examples are numerous and well chosen. The treatment of the subject by the authors is novel, and there is a marked preference for geometrical methods, but the subject matter is, as might be expected of two mathematicians occupying the high position of a university professorship, quite beyond criticism as regards lucidity, arrangement and conciseness. The book should hold its own amongst the leading treatises on elementary mechanics.

J. M. WADE, Lt.-Col., B.Sc., London.

THE MECHANICAL DESIGN OF OVERHEAD ELECTRICAL TRANSMISSION LINES.

By EDGAR T. PAINTON. (London: Chapman Hall, Ltd., 11, Henrietta Street, W.C. 2.) 1925. Price 21/-

THE author of this volume has set out to produce a book describing the latest constructional details of overhead lines for the transmission of electrical power, together with the present trend of thought on design methods.

He points out those features which experience has shown to be desirable and indicates how far the limits of commercial manufacture enable requirements to be fulfilled.

Different forms of conductor are first dealt with, copper, aluminium, aluminium steel and copper clad steel wire are described and their

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various merits compared. The information on copper clad steel wire is interesting. The tensile strength for hard drawn wire of this type is given as being of the order of 100,000 lbs. per sq. inch in the smaller sizes. Sag and stress problems are fully dealt with under varying conditions, and numerical examples illustrating the use of deduced formulæ are worked out.

Four chapters are devoted to the subject of supports; various types, from the plain wood pole to the complicated steel tower are described and illustrated. Re-inforced concrete supports are not, however, touched on.

A table is given shewing the basic loading conditions and the various factors of safety insisted on in different countries; whilst another gives the voltage, conductor material, and spacing particulars of some lines that are in operation in different parts of the world.

No mention, however, is made in this table of any line using the latest form of copper clad steel conductor.

The chapter on wooden supports is one which should appeal to the military engineer, since he will mostly deal with supports of this kind. The information given on foundations and ground re-actions on loaded supports is most valuable.

Constructional details shew various forms of insulation binding and mechanical clamps, different methods of jointing, various forms of guards and lightning arresters.

The final chapter on the erection of an overhead wire lays stress on the necessity for organization, in order that the construction may proceed in a continuous progression.

The information given is good, and provides food for thought for anyone who may have to organize an engineering undertaking spread over a large distance. An outline of such processes as insulation manufacture and design is included, in order that the reader may appreciate possible causes of failure and the reasons for particular kinds of tests.

The book has been written principally for the consulting engineer, and, generally speaking, the schemes, etc., considered are on a larger scale than anything that has, in the past, been taken on by British military engineers. In spite of this, the practical side of construction has not been omitted, and the book contains any amount of information that would be of great assistance in putting up the less spectacular type of overhead line likely to be erected by Royal Engineer officers.

G.C.G.

AUTOMOBILE ENGINES—MOTOR MANUALS, VOLS. I and II. By ARTHUR W. JUDGE. (Chapman Hall, Ltd., 11, Henrietta Street, London.) Price 4/- each.

Volume I is the first of a series of motor manuals intended to present in a non-technical manner the various aspects of each branch of the subject.

The author states in his preface that his object is to produce a book for the use of motor owners, students and others, who desire a sound informative account of the practical and theoretical side of automobile engineering.

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He manages to compress into a comparatively small volume a great deal of information, much of which is not to be found in the ordinary motor manual published at about the same price. Fuels, combustion processes, pressures, efficiencies and indicated horse power, etc., are clearly dealt with, and the two and four stroke cycles are described and compared.

Various components of the petrol engine, e.g., valves, different types of cylinder heads, valve forms and valve dispositions, pistons and piston rings, etc., are described, and their various merits compared.

Following this is an account of how these different engine components are arranged by different engine designers, examples and diagrams of almost every type of car or light car engine, from one to twelve cylinders, being given to illustrate various points.

There are, in addition, chapters on the lubrication, cooling, testing, and maintenance of the ordinary car engine. These latter, apart from being of value to the owner-driver, would be of great use to anyone who had to get up lectures, etc., for the instruction of lorry or car drivers.

Volume II of the series deals with various fuels used in motor car engines, together with the elementary theory of carburation. A simple form of single jet and air intake carburettor is then described and its various defects are pointed out; e.g., starting difficulties, acceleration difficulties, etc.

From the consideration of the defects of this simple carburettor it is possible to summarize the conditions that should be fulfilled by the perfect article.

Different methods of arriving at this ideal are then described; all the various classes of carburettor being classified in five typical groups; explanation being given as to how and why these different types fail or succeed in reaching the ideal.

The next step is to illustrate and describe in detail some 14 types of British, and 6 types of American motor car carburettor, showing how different makers strive after the ideal in different ways.

Following this is a description of a number of motor bicycle carburettors.

There is a final chapter on Testing, Tuning, and Trouble-tracing from the carburettor point of view.

The book is a good one, and should appeal to the type of person for whom it was written, viz., the motor owner, driver, garage engineer and mechanic.

G.C.G.

MAGAZINES.

REVUE MILITAIRE GÉNÉRALE.

(*November*, 1925, *continued.*)—***Ludendorff's Battles on the Russian Front.*** The conclusion of the article by General Camon, dealing with the Battles of Lodz and Augustowo, both of which were "Battles of Cannae." At the former the Russians escaped encirclement, but at the latter the greater portion of the 10th Army was taken prisoner. The conclusions drawn are that from the German success at the two

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battles of Augustowo and Tannenberg one might be tempted to think that Hannibal's tactics are better suited to warfare of the present day than those of Napoleon as applied at Insterberg (the Masurian Lakes). But it must be remembered that the Russians made the Germans pay dearly for their successes, although the counter-measures of the Russian Commander were scarcely suited to the occasion, also the Germans having secured the key to the Russian cypher were always perfectly acquainted with the dispositions of their enemy. Again, in the combats preceding the battle of Lodz the Cannae plan was not so well executed that the Russians could not extricate themselves. The fact is that the longer the battle front the fewer the facilities for encirclement; on the contrary, the greater are the enemy's opportunities for overwhelming one of the outflanking bodies while containing the other. The infallibility of the Cannae design, given the resources of modern warfare, is very doubtful.

The Ouaouizert Column in 1922. By Squadron-Commander Perney.—The operations provide no noteworthy points, except that on one occasion the main body with artillery and native levies seems to have been caught in a defile; the resulting confusion would have been disastrous with less seasoned troops and a more enterprising enemy. Some of the lessons afforded are of interest, but referring almost entirely to North African conditions, are not of universal application.

Military Chronicles of Economic Questions. By Pierre Bruneau.—This article discusses the conflicting demands of the Army and of agriculture in France on the man-power of the nation. The rapid progress made in the United States for industrial mobilization in case of war is also commented upon.

(*December*, 1924).—This is the last number of the *R.M.G.* to issue. An editorial note explains that the *Revue Militaire Francaise* having been adopted by the General Staff, and the demand for two periodicals dealing with the same subjects having ceased, it has been decided to discontinue the *R.M.G.*, at any rate for the present. Our sympathies are due to the management in their misfortune.

The Aulic Council of War in Austria, 1799-1801. By Commandant Weil; the last article written by him before his death.—An argument in favour of unity of command in war, drawn from a book by Col. Cordon on the futilities manifested by the Austrian Council of War before and after the Battle of Zurich up to the Battle of Marengo and the peace of Lunéville.

Operations of 1923 *in Morocco, near Marrakech.* By Squadron-Commander Perney.—There is little of particular interest in this article. Thanks to the investigations of the political officers before, and to the dispositions and tact of the Column Commander during the operations, all objectives were occupied with little or no fighting.

Essay on the 4th Bureau of the General Staff. The conclusion of Major Raoult's article, in which is explained with fuller detail the relations between the 4th Bureau and Artillery, Engineers, and the Army Services. Suggestions are made for possible improvements in certain particulars, especially as regards Artillery and Engineers. For the latter one store

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depot and one park were formed, generally speaking, for each Army Corps, the sites being selected by the 4th Bureau, and organization arranged for by agreement between the engineers, the road service and the 60 c.m. railway management. At first formations sent their demands to the G.O.C. the Engineers, who met them as far as he could from stocks in hand, and sent the rest to the 4th Bureau with his remarks. The writer thinks that this was wrong, that all demands should be sent to the 4th Bureau, and that the G.O.C. Engineers should only issue the amounts passed by it with his concurrence. As the war lengthened this was, in fact, what took place, the main determining factor being the necessity for concentrating all transport in the hands of the 4th Bureau. It led to the happy result of relieving the G.O.C. Engineers of a quantity of administrative work, leaving him more free to meet his heavy responsibilities to the 3rd Bureau in regard to defensive works. In view of the magnitude of his duties further decentralization was gradually effected, and roads, water supply and hutting became independent services, although, apparently, some engineer units were employed on them, either for execution or superintendence.

Conneau's Cavalry Corps on the Marne. In this article Col. Monsenergue sketched the course of the French retreat from 3rd to 6th September, 1914. Trained for shock tactics the cavalry had now learnt the impossibility of employing them against the Germans, and restricted themselves to providing escorts for their artillery, using cyclists and dismounted action with the few machine guns available. By these means they were able to close the gap between the French left and the British right and frustrate Von Kluck's determined effort to break through the gap and turn the French left. The result, after some days of struggle, paved the way for the victory of the Marne.

Books. Quelqu'un Dira? By Henri Bouvier (Jouve). Awarded a prize by the *Académie Francaise.*—A magnificent recital of the most dramatic incidents in the author's experiences of the war, which should be read by all the youth of the nation to whose lot it falls to complete the work of their elders.

Lettres à un ami. Souvenirs de ma vie Politique. By Alexandre Ribot (*Editions Bossard*). M. Ribot was Finance Minister from 26th August, 1914 until he became President of the Council and Foreign Minister from March to October, 1917. His book contains admirable pen portraits of the most distinguished French politicians and soldiers of the period, and its evident sincerity entitles it to a prominent place in the annals of the war.

Artillerie de Campagne. By Lt.-Col. Rimailho (Gauthier-Villars).—Few men are better qualified to elucidate this subject than Col. Rimailho, who was one of the designers of the 75 c.m. gun. Commencing with a short history of the weapons in use from 1870 onwards, the major portion of the book is devoted to descriptions of the guns of to-day, and is illustrated by photographs. It is pleasingly written and should interest foreign artillery officers.

L'Allemagne et la Guerre de l'Air. By General von Hoeppner. Translation and preface by Major de Castelnau. (Payot.)—General von

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Hoeppner, after being C.G.S. of the 2nd Army, in 1916 became Commander of the German Air Forces, his book is always interesting, often impartial, and sometimes fantastic.

Franchissement des Fleuves en Présence de l'Ennemi. Col. R. Normand (Fournier).—Napoleon's dictum that a river is passed wherever and whenever it is desired to do so he qualifies elsewhere by admitting that careful preparations are required. The author confirms this by examples taken from history, and from various river crossings effected during the late war. A book rich in instruction.

A.R.R.

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*REVUE MILITAIRES FRANCAISE.**

(*January*, 1925.)—*Organization by the Council of the League of Nations for the Exercise of its Right of Control in Ex-Enemy States.* By Col. E. Requin. In a resolution passed on 27th September, 1924, the League of Nations has practically and definitely adopted a system for the control of military, naval and aerial activities in Germany, Austria, Hungary and Bulgaria, imposed upon it by the various Treaties of Peace, and destined to be introduced the moment it is decided that the existing inter-allied Commission of Control can be dissolved. The system is explained, but the writer considers that its efficacy will depend entirely on the way in which its investigations are carried out. The objects of an inquiry may be known, but the methods adopted should be unexpected, and not confined to visible acts, but include clandestine preparations. The powers of the Council are unlimited, and its action should prove more effectual than that of the inter-allied Commission, the more so because its international character removes any suspicion of partiality.

An Encounter Battle—Virton, 22nd August, 1914. By Commandant Grasset. An interesting account of the battle, fought at first in a thick fog which precluded any tactical display on either side. This part ends at 8 a.m., when the German Army Commander, von Below, broke off the action, thus saving the head of the main body of the French 4th Corps from being caught in confusion in the streets of Virton. The article is illustrated by a general map 1/40,000 and three sketches. (*To be continued.*)

Material for the French, Morale for the Germans. A reply by Commandant Grenier to a pamphlet lately written by the German General von Taysen, in which the latter accuses the French of relying too much on superiority of fire and on mechanical aids for winning their battles, to the detriment of the morale of their infantry. Major Grenier considers that this pamphlet, written by a late Inspector-General of Infantry, is prompted by a desire to uphold the excellence of his own arm, and to persuade the German infantryman that he can do without the heavy artillery, tanks and aircraft, which have been forbidden to him by the

* *Copies of R.M.F. will be placed in the Corps Library for issue to members who wish to read articles outlined in this necessarily brief review.—Ed., R.E.J.*

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Treaty of Versailles. In spite of what the General now says, there is no doubt that the machine will again take its proper place in German preparations for war.

Signals in the Army Corps. A tactical exercise carefully worked out by Capt. Joubert, illustrating the organisation of signal communications of a Corps derailing, marching into cantonments, and providing an outpost line. Although wireless must be used to a great extent at first to communicate both with aeroplanes and scattered units, the writer considers that a complete telephone system should be installed as soon as possible, and as an instance asks what might have happened had von Kluck been able to talk direct with the Great General Staff at the time he abandoned his march on Paris.

Anti-Aircraft Fire and Defence. By Colonel Pagézy. This is Chapter II of an article commenced in the *R.M.F.* for December, 1924. Although somewhat discursive, it states clearly and not too technically the problems confronting the A.A. gunner, and the various steps taken to solve them. (*To be continued.*)

The Genesis of Trench Artillery. By Colonel Duchêne, of the Engineers. Interesting as a matter of history and written with some sense of humour.

Foreign Military News—Japan. A few remarks on the recent naval manœuvres, and the effect of the Washington Agreement on the numbers of vessels in the fleet.

United States. Short descriptions are given of the new medium tanks of 1921 and 1922 patterns, of the new medium guns now being tried for arming the Corps artillery, and of speed and endurance tests of naval aeroplanes.

Italy. Rifle clubs abound and technically and administratively are under the Minister for War, who supplies instructors, arms and training grounds. In these the youth of the nation is trained before being called up for service. After the War the period of colour service was eight months, which, since January, 1923, has been extended to eighteen months. Fascism is getting into its hands the pre-military training and also that of the voluntary militia for home defence.

Bibliography. Places fortes et fortifications pendant la guerre de 1914-1918. By General Lebas (Payot). Dealing more particularly with the northern end of the allied line in Europe, the writer upholds the value of fortification, and asserts that if Lille and Maubeuge had been kept up to date, and if on mobilization the works recommended by the Commission of Defence after the war of 1870 had been constructed, they would have sufficed to limit the progress of the German armies.

Cinq Ans du Turquie. By General Liman von Sanders. Translated by Lieut.-Col. Mabille (Payot). These memoirs are of great interest, furnish much information hitherto unpublished, and throw a new light on several events of the war in the East.

Un des problèmes de la Paix ; Le désarmament de l'Allemagne. André Honnorat (Alfred Costes). Supported by official documents, this work is concerned with two of the burning questions of to-day—the work

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of the Inter-allied Commission of Control and the development of the militarist movement in Germany, and is, therefore, of capital interest.

L'Infanterie allemande au Combat. By Commandant Grenier (Charles Lezangelle). A critical study of the German Infantry Manœuvre Regulations of 26th October, 1922.

Historique des Corps de Cavalerie Commandés par le Général Conneau (Charles Lezanville). A worthy successor to the histories of the cavalry corps of Sordet and Robillot, which have already been published.

Mémoires de l'Amiral Scheer (Payot). Written by one of the most senior German naval officers, and one who was behind the scenes in German foreign and domestic policy, this work is of considerable military interest. A stalwart upholder of the submarine war, Admiral Scheer expatiates on the political, economic, and military considerations which decided Germany to adopt that mode of action.

(*February*, 1925.)—*Concerning a German Opinion on French Military Ideas.* General von Taysen's pamphlet, "Material over Moral," appears to have aroused as much interest in France, at least in military circles, as generally in Germany. Reviewed in last month's *R.M.F.*, it is criticised at greater length this month by Col. Alléhaut, who begins by observing that lessons are to be learnt even from enemies, especially when they have offered such formidable resistance as Germany. The military ideas of Germany, victor of 1866 and 1870, were adopted more or less by France and other nations (it is to be regretted that they were not followed in the matter of mobile heavy artillery and the use of the spade), but it would be unfortunate for France, as victor in the last contest, proudly to consider that her ideas must now be the best. Von Taysen's criticism may, therefore, be of value to France, although this would be the last thing he would desire. But his remarks must be read with discrimination; he occasionally fails to appreciate shades of meaning in the French regulations, and sometimes reads into them words which cannot be found. Again, it is curious that the advocates of sledge-hammer methods should now be belittling the machine as a means towards victory, and to belittle one's adversary is to show one's own defeat in a more humiliating light. After these preliminary observations, the German pamphlet is dealt with chapter by chapter. Chapter I—general remarks on the French principles of battle—being dealt with in this number, arguing that the German general's contention that the French follow on all occasions a stereotyped plan is incorrect. (*To be continued.*)

Reflections on the Accompanying Artillery. By Commandant Menjaud. The need for specially designed guns for closely accompanying the infantry regiment under the direct orders of its commander is evident. In this article are discussed the best means of communicating with these guns, their number, distribution, organisation and employment, both in attack and defence, with some remarks on the effect they will have on the employment of the divisional artillery.

An Encounter Battle—Virton. Commandant Grasset's article is continued, and leaves the 4th Corps to follow the fortunes of the 2nd Corps, whose right flank the 4th was intended to secure, but of which the leading

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division was now well on its way to Bellefontaine, some miles to the north. Soon after 8 a.m. the fog lifted and von Below, meeting with strong opposition in front, and receiving word of strong bodies of French troops on his flanks, ordered his leading divisions to halt and entrench. (*To be continued.*)

The Decline of the German Effectives in 1918. By Lieut.-Col. Paquet. This article is of interest as showing the shifts to which Germany was reduced during the latter half of the war, and specially in 1918, in order to maintain the strengths of her units in the field, but would appeal more to the statistician and historian than to the general reader.

Anti-Aircraft Fire and Defence. The continuation of Col. Pagézy's article, describing various instruments in the French service, and the manner in which they are used. The duties of the different numbers in the command and gun detachments are given, with some remarks on aiming on sound. (*To be continued.*)

The Tactical Employment of Minenwerfer in the German Army. By Commandant H. Martin. A concise and well-expressed article, worthy of study.

Foreign Military News—Roumania. The new Act of 24th June, 1924, for the organisation of the Army makes a few changes, the most important of which is that commands in recruiting regions are duplicated: (i) the command proper, *i.e.*, the Army Corps Commander, dealing with the preparation for war of troops and services, and (ii) the Territorial Commander, on whom devolves the preparation for and execution of mobilisation, both military and industrial, and whose office continues in being throughout the duration of a war.

A.R.R.

REVUE DU GÉNIE MILITAIRE.

(*January*, 1925).—*A Field Railway of Standard Gauge.* The article describes the development of the railway from Dernancourt to Maricourt during the Somme Offensive of 1916.

At the commencement of the offensive the only line available was a single line which had been built by the British. This line was practically coincident with the British-French boundary and it was put directly under the *Commissaire Militaire du réseau du Nord.* The line was originally made with the idea of economising labour at the time of construction rather than with a view to an ultimate use for heavy traffic. The curves were of too small a radius, the gradients were too steep, the rails were only fixed to the sleepers by dogspikes, which were not strong enough to hold the outer rail in position at curves, and several stations were badly sited on curves or slopes, with too short sidings.

The article describes in some detail the work which was carried out during the various stages of the offensive.

The conclusion is drawn that while giving full credit to the British for initiating the system of pressing on the construction of standard gauge lines to the front line, yet in this case, hampered probably by lack of technical troops, the writer considers that the British were over hasty and lacked foresight. Emphasis is laid on the importance, while

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keeping the line as close to the front as possible, of constructing it so that it can be exploited as the front moves forward. In particular, attention is drawn to the survey of the route with its ruling gradients, the minimum radius for curves, the laying of ballast and the siting of stations so that they are capable of extension.

The art consists in arranging the preliminary lines so that the eventual improvements can be made by extension and not by reconstruction; contrasting examples of the inconvenience of transformations and the ease of extending a well-designed station are taken from the experience of the improvements of this line.

The Communications of the Fortress of Metz. A very full description of the progressive developments from 1900 to 1918.

All artillery posts had loud speakers; cables, some with dry core paper, others with rubber insulation, were buried at a depth of 1.5 metres, sometimes more.

The whole system served 3,800 "subscribers" with 93 switchboards by the end of the War.

Reviews. "*Ce qui tout aviateur doit Savoir.*" By André Laini.—This is claimed to be a classic manual on aviation, simple and complete. The five parts of the book deal with (1) Aerodynamics, (2) Construction, Care and Testing of Aeroplanes, (3) The Motor, (4) Atmospheric Phenomena, (5) Instruments.

(*February*, 1925).—"*Revues Etrangéres.*" *The Adventures of a Bridging Train in Mesopotamia.* By Major Sandes, D.S.O., M.C., R.E. This is a translation of the article published in the *Royal Engineer Journal* of June, 1924, with concluding remarks by Chef de bataillon Lazard. He comments upon the resourcefulness of engineers and their power of adapting inadequate local resources to their requirements, and discusses the relative advantages of saddle loading versus gunwale loading, noting particularly that with the slippery teak chesses of the standard equipment saddle loading made it impossible for horses and difficult for men to keep their footing in stormy weather.

The British method of forming cut by swinging a portion of the bridge is commented on; it is quicker and requires fewer men than the French method of rafts.

Chef de bataillon Lazard concluded by saying that the work done in such bad conditions and with such small resources and the results obtained by incessant efforts in a very unhealthy country do honour to the Royal Engineers.

"Là, comme partout, les camarades du Royal Engineer Corps se sont montrés des 'gallant gentlemen'; ils ont été dignes des grands chefs que leur arme a donnés à l'armée anglaise, des Napier, des Gordon, des Kitchener et ils ont fait honneur à leur belle devise: 'Ubique quo fas et gloria ducunt!'"

The reviewer feels that the Corps will the more appreciate Commandant Lazard's complimentary remarks, knowing that during recent years he has by interchange of visits seen much of our work and established himself firmly in the friendship of those members of the Corps with whom he has come in contact.

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Other articles are :—

The Artistic Taste of Vauban. An illustrated article by Colonel Normand, indicating Vauban's genius for the combination of artistic work with simplicity, economy and sound engineering.

The Earliest Military Bridges of Boats. Extract from Herodotus, describing the arrangements of Xerxes for crossing the Hellespont.

The Crossing of the Oued Bou Regreg (Morocco). A raft was made from two boats and was used for transporting animals and baggage. The camels were made to sit down on the raft; those that would not do so were made to sit on the shore and were then tied up thoroughly and carried on board; the camels succeeded in inflicting one or two casualties. More than 10,000 men, 4,000 animals and 7,000 loaded camels crossed the river in 15 days.

The Engineer Parks of the Greek Army. A description of their organisation and equipment.

(*March*, 1925).—*A Contribution to the History of the French Engineers in the East.* The aim of the *Revue du Génie* is to collect information about the work done in the Near East and the Balkans during the War. The work described in this article mainly consisted of roadmaking, camps, water supply and the exploitation of forests. The expansion of the small workshops established at the ports at the commencement of the campaign into well-equipped shops capable of a large variety of work is mentioned. The account is chiefly a historical record containing some account of the organisation and of the work done, without going into technical details.

The Water Supply of Labry Barracks. A description of the installation of a barrack water supply obtained from a deep source in the neighbourhood of mine workings.

The Military Railway Bridge on the Oued Bou Regreg at Rabat. A detailed description of a railway bridge across the River Bou Regreg. The bridge was of three 146-ft. (44m.50) spans resting on pile piers, total length of bridge 572-ft. Each span was made of six independent reinforced concrete arches with a rise of about 20-ft., giving a 16-ft. width of roadway. The greater part of the article is an account of the way in which the foundations were made in difficult ground without using any special material. The only plant used were a pile driver, a skip with jaws and standard steel sections.

Revues Etrangères. The Articulated Bridge K. (Kirchner). A translation from *Heerestechnik*, March and April, 1924, giving a general description of a type of military bridge for normal railway track, designed to cross the Save near Belgrade in 1916. The article lacks detail, but comments on several interesting points of design. By using 5-metre sections for the girder and 3-metre sections at the ends, the length of the bridge can be adjusted to the nearest metre. All sections are made similar and are interchangeable; this makes the erection uniform and simple. The bridge is specially designed for cantilever erection, the parts are few and, therefore, too heavy for manhandling, but are very simply and quickly placed by moveable derricks on the top of the girders. The girder is designed to take a normal track over a maximum span 106 metres.

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Statistical Data. This is the first of a series of articles giving notes on actual work done by engineers. The notes give general details and description of the work, the number of men employed, the time taken, the materials used and remarks. In this number examples are taken from the construction of four roads, which include details of roadmaking (various types), quarrying, stonebreaking, walls and bridge building. Also time, men and material tables for constructing and launching six light infantry bridges.

Reviews. Etude sur les Operations de Guerre en Montagne par le Lieutenant-Colonel breveté M. Abadie. An account of the lessons drawn from operations in the mountains during the last War. The author explains the use of troops in the mountains and their maintenance, particularly during winter.

Ce qu'il faut savoir de l'Infanterie. Lieutenant-Colonel breveté M. Abadie. Discusses the qualities required by modern infantry and its use and support by other arms.

L'Instruction sur l'Organisation et le Fonctionnement des Etat-majors en Campagne, 28th May, 1924. Two main principles are laid down: (1) A complete distinction between the prerogative and responsibility of Command and the Staff; (2) The necessity of intimate liaison between the Chief and his immediate subordinates.

H.G.K.W. and G.N.T.

BULLETIN BELGE DES SCIENCES MILITAIRE.

(*Nos.* 10 *to* 12 *inclusive*).

The account of the operations of the Belgian Army during the Great War is continued (Nos. 10 to 12 inclusive); events connected with the defence of Antwerp taking place on October 6th in the Sub-Sector of the 5th Division are recorded in some detail. At dawn on that morning, the headquarters of the 5th Division were at Bouchout and those of the 1st Division at Contich; and Belgian troops were still holding positions extending along the north bank of the Néthe between Rumpst and Duffel, but westward of the latter place the allied line had fallen back to positions approximately parallel to the railway connecting Boom and Broechem, part of the defending troops being westward of the railway and part eastward of it. Units of the German 6th Reserve Division had by now firmly established themselves on the north bank of the Néthe between Lachenen and Lierre; the pioneers of the Division had bridged the river and thus enabled the batteries of a field brigade to cross over and come into action on the north bank of the Néthe. Lierre was in the hands of the German 35th Reserve Infantry Regiment, which had established itself along the north-eastern limits of the town, on the south bank of the Néthe. Having realised that the Belgians were weak in artillery—the heavy guns promised by the Allies to the Belgian High Command had not arrived in Antwerp—the Germans moved their heavy artillery up to the line of the outer forts and pieces of various calibres—10 to 42 centimetres—were in action, *inter alia*, in proximity to Forts de Wavre St. Catherine, de Koningshoyckt and de Lierre. At this time, the Germans had assumed a defensive attitude and were waiting

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for their artillery to put down an effective barrage. The delay on the part of the enemy to push on was an unexpected piece of good fortune for the defenders ; the Belgian troops which had taken part in the counter-attack on the previous day had been obliged to retire to their original line running by Lachenen and Hulst to Pullaer, and the units were without cohesion and much intermixed. Had the German High Command grasped the true character of the situation and acted boldly and with promptitude, it is probable that the resistance of the Belgians in the neighbourhood would have completely collapsed ; a catastrophe of this kind must have produced serious consequences in connection with the further operations of the Belgian and British troops in this region. The troops under Generals Coveliers and Deruette had on the previous evening been grouped and placed under the command of General de Stein d'Altenstein, who still hoped to keep the Germans at bay on his front and, with this object, issued orders for a further counter-attack. These orders did not reach General Coveliers, who, during the night of October 5-6th, had moved forward first to Hulst and proceeded thence to Zevenhuyzen. His intention was to get into closer touch with the troops under his command, but, as might have been expected, he and his staff became isolated in their forward position and, after a time, owing to the intensity of the fire in this part of the field, they had continually to be shifting their headquarters ; touch was, in consequence, completely lost for a considerable time with the Group Headquarters. However, in view of the dispersion of the troops and the general situation, it is highly probable that had the orders sent him reached General Coveliers, he would not have been able to give effect to them. The orders for the counter-attack issued by General de Stein d'Altenstein were duly received by General Deruette, who, having obtained information from his subordinate commanders in order to be in a position to appreciate the situation, issued orders with a view to maintaining a hold on the river line. The reports which reached the Defence Headquarters of the Citadel on the morning of October 6th, seem to have created an impression that the situation in the fighting line was more serious than was actually the case ; in consequence, at 8 a.m. General Deguise decided that the time had arrived for him to utilise his last reserve, the 2nd Division, and he accordingly issued an order to the commander of the Division to move forward a part of his artillery and infantry to the neighbourhood of Linth. These moves were carried out. From the narrative in the original article, it is gathered that the staff arrangements at the headquarters of the British section of the line were not working satisfactorily. Information as to the disposition of certain Belgian units in this part of the Sub-Sector appears to have been faulty ; further, a proper chain of command does not seem to have been established and, in consequence, the commander of a Belgian unit received orders from the Brigadier commanding the R.M. Brigade as well as from the latter's immediate superior, General Paris ; unfortunately, these orders were contradictory and placed the recipient in a dilemma. At this time, the two brigades of the R.N.D., which had been hurried to Antwerp, were being detrained at Wilrijck and Kiel ; they were under orders to proceed to a part of the second line position, near Vieux Dieux, on the main road from

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Antwerp to Lierre. The units of these brigades were without rations and without ammunition and arrangements were accordingly made to supply them with both before they were sent forward. The situation was now developing very rapidly and it was already evident at the Headquarters of the Citadel as well as those of the 5th Division that the hour was fast approaching when the defenders would be obliged to abandon their forward positions and even retreat from Antwerp. General Paris had, on the evening of October 5th, been placed in command of the two naval brigades sent to Antwerp by the Admiralty; the Belgian High Command, apparently being ignorant of this fact, had placed these two brigades under General Dossin, who was responsible for the retrenched position prepared between the two lines of detached forts. Comment is made in the original article on the part played by the British First Lord of the Admiralty, who appears to have assumed command of the two naval brigades himself and to have issued orders to them; orders which were contradictory to those issued to these formations by the Belgians. Many most elementary rules appear to have been ignored by high authorities in relation to the conduct of the defence of Antwerp, and it is a miracle that a disaster did not follow. At 12.45 p.m., the R.M. Brigade fell back, towards Eggerseel, on to the retrenched position mentioned above; owing to the obstacle formed by the Petite Nèthe, northward of Lierre, the enemy did not follow the retiring British troops. The Germans had become extremely cautious and were no longer taking any risks. Instructions were issued at 10.10 p.m. for the troops under Generals Coveliers and Deruette to retire from their advanced positions at Duffel and Lachenen, but it was not until towards midday that the necessary orders reached those concerned. The measures taken in connection with the retreat from the Néthe are described in the original article.

The article by Lt.-Colonel B. E. M. De Grox, entitled *Le Terrain et la Guerre* is continued and completed (Nos. 10 and 11); among other articles of interest in these numbers of the *Bulletin* are *La Bataille de Saint Quentin*, by Lieut. Fraeys (Nos. 10 and 11), and 1814 *et* 1914 *en Belgique*, by Maior B. E. M. Van Egroo (No. 12).

(1925. *Nos.* 1 *to* 3 *inclusive.*)

THE account of the operations of the Belgian Army during the Great War is continued in the three numbers of the *Bulletin* under notice; therein are recorded the incidents connected with the retirement of the Belgian troops from the line of the Néthe during October 6th, 1914. Properly to understand the events dealt with it is necessary to read the account of the operations as set out in the original article; it contains matter of much interest to which justice cannot be done within the limits of space available for this notice. The part of the story which deals with *L'agonie du fort de Broechem* (in No. 1) is likely in particular to appeal to Sappers; illustrations are provided showing a part of the fort after it had been damaged by the German artillery, and a plan of the fort is given whereon are plotted, in distinctive colours, the positions of the hits made by (1) the 42 centimetre pieces, (2) the 30.5 centimetre pieces, and

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(3) pieces of which the calibre is uncertain. At this time, the Germans had reached the vicinity of Termonde, and, on October 6th, were attacking the Belgians in that neighbourhood; they were also making preparations to force a passage across the Scheldt at Schoonaerde. General Deguise, who was in command at Antwerp, in consequence, issued an order at 9.20 on this day (addressed to the 6th, 4th and 3rd Divisions, then in No. 4 Sector of Defence), directing the 6th Division to support the 4th Division; to the latter was assigned the task of preventing the enemy gaining a footing on the left bank of the river within its zone of defence. The outposts of the 6th Division were withdrawn without incident, the 3rd Division taking over from the 6th the latter's part of the front in No. 4 Sector. The 3rd Division had now to hold a front of about 12 miles with six battalions; in view of the wide extension of the front he had now to hold, coupled with the fact that the enemy was attacking Fort Breendock with vigour, the Divisional Commander, who had no reserves at his disposal, became much concerned and reported the situation to G.H.Q. in Antwerp. Fortunately, the enemy was content to confine his activities to artillery action, and no infantry attack was launched in combination with the bombardment of the "heavies." A few particulars are given in the original article concerning the bombardment of Fort Breendock, a bombardment which was temporarily suspended by the Germans on October 7th, but only to be resumed on the following day. During the first bombardment, a cupola containing a 15 c. gun was hit and put out of action, the caponiers were seriously damaged and the barrack-rooms in the fort were rendered uninhabitable; however, in no case were the vaulted roofs pierced, nor was the armament damaged.

In an article entitled *Les destructions* (in No. 1) Capt.-Comt. B. E. M. Beretze-Colet, having briefly reviewed the pre-war French and Belgian regulations relating to demolitions, describes some of the important demolition work carried out by the Belgians and the Germans during the Great War, and points out some of the lessons which the experiences of this conflict teach on the subject. The present day views held in France, Belgium, Great Britain and Germany on the subject of demolitions are also dealt with in the original article, much matter of interest being compressed into a relatively small space.

Major B. E. M. Heirman contributes an article to the February number (No. 2), entitled *Quelques Considérations sur l'emploi du Génie;* it is an interesting summary of work done by the Belgian Engineer Arm in the Great War, and contains suggestions in relation to the better utilisation of this arm in the future. In a short introduction Major Heirman points out that the duties upon which the Belgian engineers were employed during the Great War varied very considerably; at no time were any precise and definite regulations framed with a view to determining the manner in which the services of this arm could most usefully be utilised. In the early months of the war, the divisional engineers were divided and again sub-divided into a considerable number of small parties, which were attached to units of the other arms; the dispersion was very great and no indication was given as to how the engineers should be employed. In consequence, during the first phase of the great conflict,

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the engineers did quite a lot of marching and were always at hand when fighting was going on, but, unfortunately, they were not given an opportunity of doing any really useful work of a technical order. However, once the opposing forces settled down to the realities of trench-warfare, every advantage was taken of the specialised knowledge and training of the Belgian sappers; at the same time, it soon became apparent that there was a great deal more technical work for the sappers to do than there were sappers to be employed thereon, and, therefore, working parties, drawn from the other arms, had to come to their aid. Later in the war, in fact, during the Entente offensive of 1918, the problem of restoring the communications destroyed by the retreating enemy on a colossal scale on a comprehensively planned scheme became a matter of high importance; the solution of this problem engaged the attention of the Chiefs of the Engineer Arm. The task of making good the damage done was assigned to the sappers, and they became, in consequence, the *arme des communications;* their chief effort had now to be concentrated on the work which had to be carried out to enable the other arms to keep touch with and, if possible, to overtake the great hosts who were hurrying back to seek safety in the Fatherland. The main part of the article is treated under two heads :—(1) *Le génie comme arme* and (2) *Le génie comme service.* In conclusion, Major Hierman points out that, to ensure that the Engineer Arm shall be effectively and efficiently employed in a Theatre of Operations, it is essential that the engineer units should carry out their work under the control and direction of their own chiefs. Consequently, if engineer units are widely dispersed and removed from the control of their own commanding officers, and the latter are not provided with the working parties required by them, the inevitable result must be that the utility of these officers will be destroyed and the specialised work which ought to be carried out under their direction must at the same tine suffer in design, quality and punctuality of performance. Finally, Major Hierman considers, rightly, it is thought, that a three-fold rôle attaches to an officer occupying the position of a C.E. or a C.R.E.; the duties which rightly appertain to officers occupying such positions constitute them, at one and the same time, technical advisers, commanders of troops and administrative chiefs of a service.

Certain works have appeared in France which deal with the defence of Namur; they are reviewed by Capt.-Comt. B. E. M. Herbiet in the March number of the *Bulletin* (No. 3) in an article entitled *La Défense de Namur en* 1914.

W.A.J.O'M.

MILITÄRWISSENSCHAFTLICHE AND TECHNISCHE MITTEILLUNGEN.

(January-February and March-April numbers.)

MAJOR Franz Stuckheil continues his history of the offensive period of the garrison of Przemysl during its second investment.

The Battle of Limanowa led to hopes of co-operation between the Austrian 3rd Army and the garrison and a really serious attempt was

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made on the 15th, 16th, 17th and 18th of December, 1914, to breach the Russian lines by sortie and to threaten the Russian retreat. As it turned out the Austrian third Army had no further success. But the sortie, in which about two divisions (24 battalions, 15 batteries, etc.) took part, actually did break the Russian lines, and was in a position to have given valuable aid to a further Austrian advance.

The action is well described and illustrated.

Captain Fritz Heigl contributes an article on the art of smoke-screening, which well repays study. The subject is well written up and the experience of all armies drawn upon.

The objects of smoke-screening are :—

1. Prevention of tactical and visual observation.
2. Prevention of aimed fire.
3. Deception.
4. Simulation of poison gas and enforcing gas masks.

Smoke from projectiles and smoke from nozzles or containers fill different roles. The one to cloud the enemy, the other oneself. Different smoke producers are compared with respect to density, poisoning (which must be avoided for obvious reasons), endurance and availability.

French, English, American, German and Italian apparatus and producers are enumerated and the expenditure of ammunition compared.

As an aid to the offensive, the first point brought out is the hiding of artillery concentrations forward and the main offensive role of smoke may be considered to be the denial of observation to O.P.'s. It should be used, where possible, to help and simulate morning and evening mist. Tank concentrations the same. The experience of French tank attacks is quoted at length. Heavy artillery and even field artillery may be made powerless against opportunity targets (*e.g.*, tanks), although not against fixed ones, for which adequate location, calibration, and meteorological measurement should suffice. Tanks may cover the advancing infantry or their own retreat. Aircraft envelop the target (ship or factory) with low-lying smoke (bombs), which will define the target and yet render it powerless, or conceal their movement by high thin clouds. Aircraft offer the cheapest and best screen against O.P.'s in the thin continuous curtain. River crossings, attacks on prepared positions, and temporary delays due to local strong points, call for the smoke masking of bridges, of the trench objective, or of flanks respectively. (The 9th Divisional attack north of the Scarpe in 1917 is quoted.)

As a defensive measure, the author is not on such sure ground. He is frankly of two minds as concerns the defensive value to the artillery itself (he is a gunner). It is possible to avoid direct observation, impossible to "spoof" the sound ranger. Possible to avoid bombs and the eye above, impossible to get "line" from a respectable R.O. He himself, with a howitzer battery, secured a four hours' life on the Piave (June, 1918) against heavy concentrations from Italian batteries by this means, but could only see his night R.O., does not think much of his own shooting, and was finally knocked out by an area concentration. On the other hand, if the whole of a defensive area is screened (thinly,

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as by mist), after good preliminary survey of the approaches and likely positions in front, the defence stands to score and the immediate danger is the soundranger. The front line and the field of fire, on the whole, are better left (to secure best fire effect), but the approaches, for supports, reserves, etc., should be masked.

The obvious drawbacks of smoke screening are that you cannot spoil the view for the other fellow and retain it yourself, and that it adds yet another weight on transport, and on the industrial " home front."

Nothing is said of the value of smoke in orienting the attack and parcelling the objective.

The student of the German plan of campaign will be interested in "East or West Front," by Colonel Kiszling. He thinks Schlieffen's plan of campaign was out of date in 1914. Although Germany's industrial areas and mineral reserves lay near her eastern and western frontiers the latter were, none the less, easier to defend. France, by far the tougher and more dangerous enemy, could not be squashed in six weeks. A concentration on the Russians might have had immense effect, brought in Bulgaria, possibly, too, Roumania or Sweden, or both. The political effect of the infringement of Belgian neutrality was a far greater burden than had been contemplated.

L., who recently wrote an article on the place of the Air Arm in the State, now writes under the title "Final Decision in the Air?" The final decision is generally won through a variety of factors and ends generally in the actual occupation of enemy territory. L. thinks, then, that no actual decision can be considered " in the air," but that it may be " through the air." It is impossible to imagine a three dimensional battle of aircraft which in itself shall be decisive. In fact, the action of aircraft must, like that of a blockade, work indirectly rather than directly. In the indirect sense, however, it is extraordinarily important and extraordinarily hard to combat, because anti-aircraft measures are robbed, in the main, of mobility. They must, in fact, be arranged as more or less stationary defences for the vital spots of a nation. They may be effective, peculiarly so with an adequate equipment of search-lights, but can never be absolute, or do more than to add to the risks of the aircraft. They may be such, however, as to prevent the success of massed attacks, and, without massing, aircraft lose much of their offensive power. By analogy with wasps and other insect plagues, the author considers they are best attacked on their breeding grounde by the destruction of aerodromes and aircraft factories. Even so, however, in a highly developed state there will be so many opportunities for repair and so many places where landing is possible, that such measures will be very difficult to carry out. In fact, logically speaking, it is possible to consider two States at war whose respective aircraft shall be so powerful as entirely to cripple the States themselves, whilst the respective air forces remain comparatively innocuous to each other. He does not think that the term "command of the air" can ever be strictly applied in the sense in which we think of the "command of the sea." If an actual decisive battle is sought, then aircraft must act with the sailor or soldier. With the sailor, L. thinks his contribution not very large in actual battle, though all important to reconnaissance. With the

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army, his help may be of very great value—on occasions being decisive.

With regard to war upon the country and the civil population, the vital spots may, of course, be attacked, and, therefore, States of the largest population and of the highest organisation are the most vulnerable. Unfortunately, it will not be possible to ensure the destruction of such politicians as temporarily rule the destinies of the State. However that may be, there will always be a large population living in more scattered wise upon whose patriotism and strength of will fresh resistance may be built up.

An article by Captain Heigel describes the French *char de rupture*. He claims no extensive knowledge of this tank and compliments the French on their successful measures of secrecy. General Estienne is really responsible for the appearance of this tank, and his opinion as to its use is quoted frequently. Dimensions are 10.275 metres long, 2.95 metres broad, 4.015 metres high. It has 45 m.m. of armour forwards, and 22 m.m. on sides and back. As armament it carries one 155 m.m. gun and four machine guns, or, alternatively, one 75 m.m. gun and four machine guns, with a garrison of 10 men; but the author thinks that probably many more machine guns are mountable than this and considers that the number four has been cleverly spread around as a false impression. The caterpillars are not armoured or protected in any way. The tank can climb over obstacles of 1.7 metres in height. It is engined with 250 horse-power. Its role in war is to destroy those anti-tank weapons which the lighter and more mobile tank cannot deal with, and to open a way for them and for the Infantry. There is no good manual as yet written for its employment, which tends to show that the ideas concerning its use are not yet fixed.

Colonel Rudolf Rieder contributes an article on the heaviest guns which accompany a field army. The old division between field and heavy, on the one hand, and siege, on the other, has ceased to have practical meaning, since the heaviest of guns and howitzers have come to be employed in the field army and to be entrusted with more or less the same tasks as, and to be placed side by side with, the smaller calibres. The old siege material had nothing like the mobility of the guns which accompanied the troops. The Russo-Japanese War showed the extreme importance of heavy artillery, so mobile as to be brought up almost at once by investing troops against the permanent defences of a fortress. The Austrians took up the task of making their then heaviest howitzers fully mobile with mechanical transport. The 24 c.m. and later the 30.5 c.m. howitzers were made mobile accordingly, but as the bridges of Austria were not capable of carrying the whole load it had to be divided into parts, and as the existing patterns of motor lorries in Austria were not capable of taking the weight over soft ground, special waggons had to be made. These howitzers were used in the first attack on Belgian and French fortresses. The Germans, though not so fully prepared, were able to take their part with howitzers of a lesser size. The war immediately developed into a combat of the heaviest calibres, drawn partly from naval and partly from fortress material. On the side of the Allies these were mostly railway guns with small field of fire, and all the troubles consequent on the building of spurs and possible duplica-

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tion of the permanent way. The Austrians, on the other hand, faced with warfare in mountainous country (both in the Carpathians and in the Carso), arranged eventually to make their heaviest calibres mobile on petrol electric carriages, either for railway or for road. Some details of these carriages are given and of the calibres which were employed in this way.

H.St.J.L.W.

HEERESTECHNIK.

(January, February and March Numbers.)

THE January number opens with a long article on the Berlin Motor Exhibition of 1924. German and Austrian cars only are dealt with.

In the March number the Amsterdam Exhibition of February last is reported, and includes details of practically all European and American models.

An article in the *Militärwissenschaftlichen Mitteillungen* of last August gives rise to a long discussion on the tactical and technical aspects of modern war and leadership. The pre-war German staff officer, gunner and infantryman considered technical matters as bad form. Horsemanship was almost the be all and end all of the gunner. The French artillery was superior, and even giving full credit to the offensive spirit and dash of German troops, their officers had insufficient sympathy with, and understanding of, modern progress either to foresee, or to allow the development of, more efficient technical method. Specialists are necessary, but if regarded as " wild men " will become so, and a collection of wild men in charge, each obsessed with an idea, is unthinkable.

The officer and pre-eminently the staff officer must have so much technical and scientific interest and understanding as to allow him to judge of the soundness of technical invention. The staff officer should understand predicted shooting, the work of the artillery survey company (location and battery survey), the same problems of the machine gunner, the probable effect of their fire, and the results to be expected from the ammunition available. He should be able to gauge the effect of meteorological factors on gas, artillery fire, sound ranging and flying. He should understand the survey problems of Artillery, Infantry, M.G., and R.A.F., and be able to co-ordinate them. Maps, signals, wireless, mechanical transport, must be well understood. An educated person !

January and February numbers contain a short article on armoured trains. Austrian and Russian armoured trains existed. The former were used on the Russian and Roumanian fronts, to cover advance and retreat respectively. The Germans had none ready, but used some temporarily prepared in Belgium, to secure the country after the advance, in France and in East Prussia and Poland, to reconnoitre ahead. In 1918 German armoured trains were useful in Russia. The largest, best equipped and armed trains mentioned were those used by the French in Cilicia in 1920.

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In February appears the first of a series of articles which are to deal with questions of gunnery and ballistics. The first is on the necessity for, and possibility of, a system of calibration in the field. The Boulangé, Duda, Aberdeen and other chronograph systems are discussed, after a good but somewhat unoriginal analysis of the corrections for the day.

Heerestechnik has already raised the question of the best small theodolite for military purposes. The matter of a survey of sufficient precision to serve the needs of indirect fire, not only for artillery, but for machine guns and trench mortars is, obviously, taken very seriously. In the February number certain models are discussed, including the latest Zeiss. But this model, good as it is, probably represents an earlier stage of the model now made by Wild, of Switzerland, and would seem then to be already, in certain respects, out of date.

Major Kretzschmann describes the damage done to temporary bridges over the Polish rivers by ice and floods after a thaw. Naturally enough, the larger the span, and the more room for the ice to get away, the less was the damage, but in a large number of cases railway communication was interrupted. Every pier in such cases should be armoured and upstream an ice breaking triangular erection of piles made. Carpenters' joints should be used, as well as bolts, to take the thrust and prevent trouble from sheering.

Major Klingbeil reviews two manuals—"*Bridging*, Part III.A., *Heavy Bridging*," and Volume VI of the Pioneer manuals for all arms, "*Camps and Hutting*." The reviews are interesting, but do not indicate much of importance.

The third volume of *Der Grosse Krieg* 1914-18, edited by M. Schwarte, is reviewed in the March number.

H.St.J.L.W.

VOINA I MIR.

No. 15 (*continued*). THIS number also contains the first part of an article by Engineer Captain Hegel, of the Austrian Army, on "Artificial Cloud," which is illustrated by several photographs. He says that cloud was first used in the naval battles of 1914. During the war its use was in an embryo state; there is no doubt but that in future wars it will acquire great significance. He describes the objects for which cloud will be used, the various means of spreading it, the materials employed and the properties of the ideal cloud. He states the methods adopted by various armies, French, English, German, American, and Italian. He then considers its tactical application with reference to artillery, tanks, infantry and aircraft, and during the forcing of rivers, citing its use by the Austrians at the crossing of the Piave on June 13th, 1918.

No. 16. In the war-technical section there is the completion of Captain Hegel's article on "Artificial Cloud." In it he discusses the use of artificial cloud (or smoke as we call it) by artillery and infantry in the defence, explaining the difficulties and advantages. He considers the use of smoke by artillery an advantage, provided accuracy of shooting is not impaired, and especially so if used continuously from the moment

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a new battle position is occupied. He considers that smoke is worse than useless for infantry in forward positions, as it prevents accurate fire, but is most useful for covering movements and dispositions in rear.

He discusses the use of smoke for the defence of the interior of a country from aerial attacks. The English, and more so the French, now consider their chief task to be the defeat of the rear, *i.e.*, industrial centres by means of aircraft. It is a maxim that aerial attack can only be successfully opposed by an aerial fleet, but a defeated country would not possess an aerial fleet, and its single hope of salvation would be in the use of smoke. An example is then given, showing how smoke could be used to screen a town. It is shown by means of plans that smoke should be applied in such a way as to conceal, not only the town up to the limits of its extent, but any conspicuous object beyond; for instance, in the case of large barracks on the edge of the town with two ponds a few hundred yards away, if the ponds were not screened as well as the barracks, they would remain as an indication of the position of the latter.

Some remarks are made about the technical application of smoke. According to an article by Colonel Chédeville, in the *Revue Militaire Francaise*, when the French apparatus Berger and Verdier are used, to screen 15 square kilometers for a period of 2 to 2½ hours, 6 tons of chemical material would be required, and from 6 to 12 specialists per square kilometre.

He describes how false impressions could be produced by making the smoke denser or thicker in certain localities. For instance, the line of a river flowing through a town might be represented by a denser line of smoke parallel to the real course of the river, but several hundred yards distant from it, and dense patches of smoke might be laid at the correct relative distance from the false line of river to represent the positions of important buildings.

A.H.B.

COAST ARTILLERY JOURNAL.

(*August-November*, 1924.)—*Anti-Aircraft Doctrine.* The author lays great stress upon the necessity for a very detailed and thorough "indoctrination" of the theory and correct policy of anti-aircraft defence, which should be so absorbed into the being of the local commanders as to become a second nature. This would ensure that their mental processes on any given occasion would be as like that of the high commander as is humanly possible. The opportunities for action are so fleeting that a better result is obtained by decentralization so long as the mind of the local commander is trained to work along the recognised channel.

He says, "Our primary arms are (*a*) the A.A. Gun Battery, (*b*) the M.G. Battery. All other elements of the command exist for the purpose of placing and keeping these primary arms in action."

In addition to this primary role the Searchlight has a direct offensive function of considerable importance, in that the beam, even when un-

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attended by gunfire, confuses and demoralises the night flier, and may prevent him from accomplishing his mission, backed up as it is by the threat of deadly assault by the gun or defending aircraft. It is only necessary to read the personal narratives of night flying pilots, or to listen to their conversation, to appreciate the great moral effect which the systematic and unhesitating use of searchlight beams has upon them when they are approaching their objectives on the ground. They know that once the searchlight succeeds in laying on them they become the potential target for every gun and aeroplane within reach—an experience to be avoided as far as possible. Many air raids have been stopped short of their objective simply by a searchlight display while the attacking units were still far enough away to give their commanders time to think matters over before venturing further.

Communications from higher commanders to local commanders will normally have to do with :—

1. Strategic disposition of mobile reserve units.
2. Dissemination of information.

The latter of these two items is of the utmost importance to enable the local commander to make the same estimate of the situation as his commander would make if he were present.

It is more essential in an Anti-Aircraft Command, than in any other, that the fighting system should be based upon indoctrination rather than upon detailed battle order, because the essence of Anti-Aircraft action is time.

D.M.F.H.

THE MILITARY ENGINEER.

(*March-April*, 1925.)

Civil work of the Corps of Engineers.—An account of the river and harbour maintenance work for which the U.S. Engineers are mainly responsible.

Military Railways in the World War.—The evolution of the railway organisation behind the A.E.F. Contains interesting statistics showing the large quantities of rolling stock and track supplied, and the Government organisation for production and shipment.

The Training of Engineer Officers.—A cadet spends four years at West Point. After a period of service with troops, he undergoes a year's course at the Engineer School—a military institution. This is followed by one year at a Civil Engineering College, where an engineering degree is obtained.

Demolition of Linda Vista Bridge.—Experiments carried out on a reinforced concrete bridge to test the accuracy of the formulæ in the *American Field Manual*. The results tend to show that to destroy reinforced concrete, two separate charges are necessary, the first to expose the rods, and the second to cut them.

R.I.M.

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PALESTINE EXPLORATION FUND.

QUARTERLY STATEMENT, APRIL, 1925.

In this number General Sir Charles Warren, G.C.M.G., K.C.B., F.R.S., writes a short article on *The Diamond Jubilee of the Palestine Exploration Fund*, from which we may be allowed to cull the following extracts on a subject so intimately interesting to the Corps, which has sent to the work such distinguished men as Earl Kitchener, General C. G. Gordon, Sir Charles Wilson, Sir Charles Watson, Colonel C. R. Conder and Sir Charles Warren himself. " The basis of the movement was the accurate Ordnance Survey of Jerusalem (and its water sources), at present in use, carried by out Captain C. W. Wilson, R.E., in 1864-5, the necessary funds for which were supplied by Miss Burdett Coutts. This survey was followed up by a rapid examination of all Palestine by Captain Wilson and Lieutenant Anderson, R.E., and the conclusion they came to was that the most interesting site in the Holy Land for exploration was the Holy City itself."

" In the autumn of 1866 I had recently returned to England after nearly seven years in the Mediterranean, and I was offered the post of explorer to the P.E.F. I took it up early in 1867, and held it for three years, until forced to relinquish the work through malaria contracted in the souterrains of Jerusalem. In relinquishing the work I called attention to the fact that the most pressing work in Palestine at that time was an accurate Topographical Survey of the Holy Land, because treasures underground would keep safely a few years longer, but, above ground, the march of civilization was causing a disruption of all the Holy sites, and most valuable relics were being burnt up into lime.

" Accordingly the Survey of Palestine was next taken up and carried out most successfully by Lieutenant C. R. Conder, subsequently assisted by Lieutenant H. H. Kitchener. Let me state in parenthesis that since 1871, there have been very few excavations in the very ancient sites of Jerusalem. We all had to await more favourable circumstances for such work, and the time has now struck—fifty-five years afterwards.

" My work during those years in Palestine consisted chiefly of excavations in the Holy City and reconnaissances of the Plain of Philistia and the Jordan Valley. At first money failed to flow into our coffers, and for months we were at our wits' end as to how to survive the crisis. The Committee sent me S.O.S. messages, ' Get results and we will send you money,' and I retorted ' Send me money and I will get you results.' George Grove telegraphed ' For Heaven's sake find the Tomb of David or we shall be bankrupt,' and I replied ' If I do find the Tomb of David I shall certainly seal it up again : such good things are not for the like of us.' I firmly believe that up to the day of his departure George Grove had an uneasy notion that I had struck the Tomb of David and, on account of my views about the desecration of tombs, would not give it out to the public."

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But Sir Charles looks upon controversy as the chief means of obtaining subscribers to the Fund. "I do not think that there can be any elucidation of the problems of the Holy Land without controversy and criticism" "For many years we had a *Controversialist-in-Chief*, in season, out of season, he blossomed forth in some new theory and we found our wits sharpened up to keep pace with his propositions. I should guess his speculations brought in at least £1,000 a year to the coffers of the P.E.F."

"I sincerely trust that what I have said in this paper will not be agreed to by all, but that it will arouse the antagonism of many who may think my observations worth powder and shot, We want to be on the war-path to succeed. I consider that controversy is the breath of life to undertakings like the P.E.F.

"As for myself, I am ready to fight on any of the theories I uphold, but how can one enjoy shooting if one's antagonists lie low or hold up their hands?" And Sir Charles is nearly 88!

He offers a donation of £100 towards excavations on the ancient site Hill of Ophel (Jerusalem), south of the Haram Esh-Sherif, provided forty-nine other persons will subscribe £100 each, making in all £5,000. The money to be collected before 1st April, 1926. Sir Charles Close has been recently making a survey of the Hill.

F.E.G.S.

OFFICIAL HISTORY OF THE WAR.

A preliminary draft of the first six chapters of Volume III, dealing with the events on the Western front, December, 1914—March, 1915, to the end of the battle of Neuve Chapelle, has been prepared in type-script. It has already been seen by a number of the principal officers who took part, but it has not been possible to get into communication with all and obtain their views as to its general accuracy and completeness.

The compiler will be glad to send the typescript on loan to any officer who was present, for remarks and additions.

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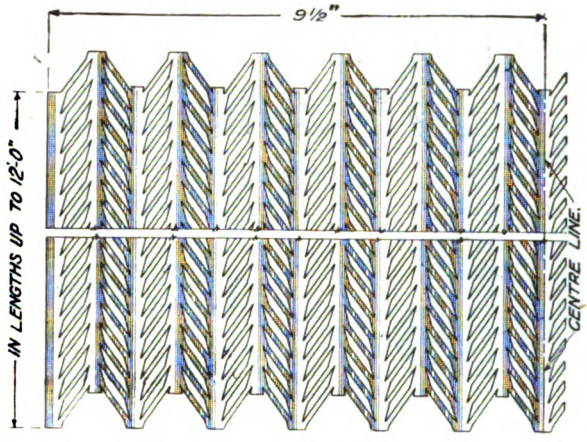

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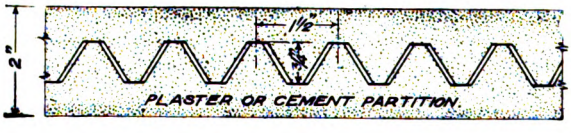

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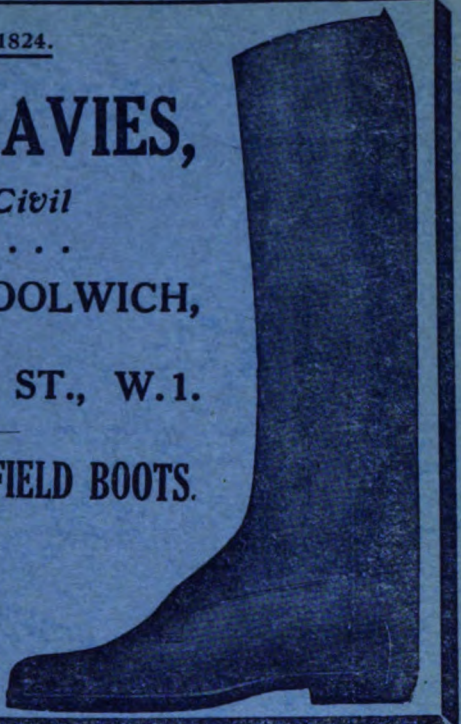

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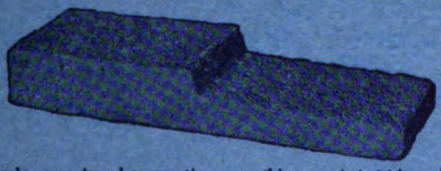

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THE ISHA-RAZMAK ROAD.

COMPILED FROM INFORMATION SUPPLIED BY OFFICERS WHO TOOK PART IN THE WORK.

THE POLICY.

THE advance of an Afghan Army in 1919 over the Durand Line into independent territory caused another of the periodical " flares " on the North West Frontier of India.

In the tract between the Kabul River and the Gomal, the Tochi and Wana Wazirs naturally sided with the invader, and as we had not the regular troops available to support them, the militia garrisons of Wana, in the south, and Datta Khel, in the north and Upper Tochi, were withdrawn.

The Mahsuds, living in the strategical heart of Waziristan, had always been the crux of the situation. Their strength lay in their inaccessibility. Now, although occupation of their territory was not beyond the powers of the Indian Army, the costly system of punitive expedition followed by withdrawal, was most certainly beyond the financial powers of the Government of India. A new policy was formulated which did not intend occupation by regular troops, but had resort to the principles so ably demonstrated by Sandeman. When a man's livelihood is raiding, it is not economically sound to simply keep on denying him this means of existence; it is also necessary to give him some other form of occupation, and consequent livelihood. The new policy aimed at informal control by means of Scouts (really the old militia much enlarged) and *khassadars*, backed by regulars. The employment of regulars necessitated communications, and a combination of irregulars and roads was less costly than regulars and roads.

Wana was re-occupied in 1920-21, and Datta Khel in 1921-22. Even so we were no nearer the main objective. The next move was to join Jandola to the Tochi by means of a road passing through Razmak. The occupation of Razmak, above and behind the Mahsud defences, was calculated to eliminate their inaccessibility, have a sobering effect on the barbaric characteristics of the Mahsud, and finally to form a healthy advanced base for the regular troops needed to support the irregulars, who were charged with the policing of the territory in detail. This policy, then, whilst providing an insurance against the abnormal frequency and cost of punitive expeditions, provided a form of employment for a large percentage of the population which was at once to their liking.

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The line to Razmak from Jandola not only passed through Mahsud country, but also followed the very difficult line of the Takki Zam, which required a huge permanent picket garrison to make it safe pending a more reasonable attitude on the part of the Mahsuds. The line from the Tochi to Razmak, on the other hand, ran, throughout its length, in Wazir country, and was, on the average, more open.

FIRST RECONNAISSANCES.

It was decided to build the portion from the Tochi to Razmak first, and establish there the regular garrison; afterwards, under the protection of this garrison, to join the line down the Takki Zam to Jandola. Practically no engineer intelligence existed regarding the line between Razmak and the Tochi, as troops had marched over it last in 1860. No survey of the intervening ground had yet been made. At the beginning of May, 1922, the only data available for a road were the northern starting point and the southern finishing point. Looking back, it is clear how imperfectly the magnitude of the job to be accomplished was realized. The first reconnaissance on the ground was carried out by a composite party consisting of Major Deed in charge of the whole project, the Political Agent and the officer in charge of the survey party, with several officers from the Tochi Scouts, who knew some of the ground slightly. This party confined their energies to the location of ruling points, such as passes, bridge and causeway sites, and, hardest task of all, steered the alignment past villages, fields and graveyards.

An aerial photographic survey was made of the Khaisora, but as this gave no idea of slopes, was of little value. At one time the conclusion was reached that the plane had gone up the wrong nullah, so that little help was gained from this source. The survey party followed later, filling in between ruling points.

THE ROAD.

The work of construction was entrusted to Capt. (now Major) L. C. B. Deed, with Lieut. M. R. Jefferis as his assistant.

The Khaisora sub-district, Military Works Services, was especially formed for this project, and, when orders to proceed with the work were received at the end of May, 1922, headquarters were first opened in Bannu.

The general instructions regarding the performance of the work specified a second class road with causeways replacing bridges—it being intimated that the Tochi river would probably be bridged at a later date. Twenty-seven miles of road were required to pass light M.T. up to Milogai by December 5th, 1922.

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The staff for supervision was to be obtained for the most part by advertisement, whilst contractors, and protection for the labour employed, were to be subject to the approval of the civil political authorities.

The funds sanctioned for the road, including the Tochi Bridge, were 1.6 lakhs of rupees per mile, making a total of 65 lakhs. Abstract estimates were to be submitted for sanction, and funds allotted, before any new work was commenced, the rates being those already paid to the Mahsuds in South Waziristan.

The specification was, roughly, as below :—

Twenty foot roadway, 12-ft. metalled with 4-ft. earth berm on each side. Two-ft. extra on each side allowed for drain or parapet wall.

Maximum gradient 1 in 13.

Minimum radius of curves, 35-ft.

Culverts, eight per mile, with a width between parapets of 20-ft. (16-ft. for minor bridges).

Soling, 13-ft. wide, 6-in. thick—9-in. on embankments.

Camber on the straight 1 in 40, with super-elevation on curves as necessary.

Causeway specification :—Road width (over drop walls), 18ft. ; down-stream drop wall of H.D. stone in cement on cement concrete footing, thickness $\frac{1}{3}$ x depth, taken down $1\frac{1}{2}$ times depth of flood + 5-ft. ; up-stream drop wall $1\frac{1}{2}$-ft. thick, taken down 3-ft. (depth to be increased if causeway not square across the nullah), flooring 4-in. p.c.c., 1 : 2 : 4 (shingle aggregate) on 8-in. lime concrete on 1-ft. hand-packed boulders.

The rates for work were :—Earthwork, Rs. 8/- ; conglomerate, Rs. 25/- to Rs. 35/- ; soft rock, Rs. 56/- ; hard rock, Rs. 75/- to Rs. 100/-.—all per 1,000 c.f. Lime masonry, Rs. 80/- ; cement masonry, Rs. 120/- ; revetment walling, Rs. 33/- for $\frac{1}{3}$ hammer-dressed, Rs. 46/- hammer-dressed throughout ; boulder walling, Rs. 5/—all per 100 c.f. Soling laid and consolidated, Rs. 10/- ; metal collection, Rs. 3/- ; metal consolidation, Rs. 10/—all per 100 c.f. Lime concrete, Rs. 45/- ; cement concrete, Rs. 133/- per 100 c.f. Earth lead, Rs. 1/- per 100 r.f. ; other lead, 2 annas per maund per mile. Coolie wages, Rs. 4/- ; masons, Rs. 2/8 to Rs. 4/8 ; donkeys, Rs. 1/8 ; camels (alleged), Rs. 5/-.

The work was divided into sections, the length of which depended on the amount of work required in each and on the capacity of the contractor obtained for that section.

The supervision staff varied, but was usually one S.D.O. for two sections (maximum), one sub-overseer and two *mistris* for two miles, one *mistri* on each group of masonry works, and one sub-overseer continuously on levels, for pegs were always disappearing. Important sections had their own S.D.O.'s. Two contractors

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well at work were the most that an officer could properly look after—problems cropped up almost hourly, usually completely defeating the subordinate on the spot. Often these problems were of the nature of a pistol at one's head from a local inhabitant, rendering the stalwart M.E.S. subordinate more ready to make tracks for home than to give a decision.

Section estimates, as required by Headquarters, were only approximate, giving the sub-work, rate, total quantity and total value, but no details, and were accompanied by plans, reports, specifications, etc. Allowances for contingencies and protection were added to the gross amount. Detailed estimates were made later and were sanctioned by competent authority. These, in the case of sub-works, laborious or difficult to estimate—such as earthwork—were prepared in the form of lump-sum estimates. Such simple estimates were allowed in order to keep the officers free to push on the work. Accounts were kept by section and sub-work.

At the end of June, 1922, the headquarters were moved to Idak Camp, some 30 miles nearer Isha on the Tochi Road, at which point the Razmak Road commenced. At Idak was opened the tool and store dump, which gradually assumed immense proportions and was very ably run by Glazebrook.

Latterly a Financial Adviser was appointed from the Accounts Audit Branch, who was always of great assistance. His attachment established a precedent which should be followed in all future projects which may be carried out under similar conditions.

LOCAL POLITICAL SITUATION.

To understand fully the situation at this period, reference must now be made to the political situation. To all intents and purposes we were at peace with the Wazirs, who, by sub-sections, own the whole of the land on which the road was to be built. The actual boundary between Wazir and Mahsud is debatable for as long a period as any other question on the Frontier where a Wazir is concerned. Wazir territory is generally held to end south of Razmak Camp at the Shuran Algad.

In June, 1922, we had not recommenced, as far as the Wazirs of this tract were concerned, the system of " doles " or allowances, which, it can be appreciated, do so much to endear us to the inhabitants of the Frontier. Hitherto, these doles were paid only to *maliks*, who might or might not exercise their influence on our behalf over their sub-sections. The new policy was to get at the rank and file of the tribes, our faith having been somewhat shaken in the efficacy of *maliki* control. It was this idea which produced the " khassadar." The tribesman is undoubtedly what the babu calls " military man." He has a weakness for carrying a rifle

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and a most unholy loathing for the shovel. Possibly when we have reversed this preference and stimulus is given to the "arts and crafts" and village industries, the Frontier problem will be nearing a settlement.

At a *jirga* held at Miranshah, the proposition was put to the Wazirs interested, and it has been officially reported that they invited us to proceed with the road, which would assist them against their ancient enemy, the Mahsud.

Subsequently, much *kurcha* was paid out, allowances fixed, and the enlistment of Wazir *khassadars* begun. Here a deviation to say, that unless you have seen *kurcha* paid out to Wazirs, seen their mouths dribbling at the sight of the bag of silver rupees, you cannot realise the hold of money over the tribesman.

Broadly speaking, the *khassadars* were directly under the Political Agent, and were stationed at such centres as Jaler, Tal, Asad Khel, etc., whence they occupied picquet posts along the road.

Badraggas, on the other hand, were under the M.E.S., and were responsible for guarding the road supervision staff, M.E.S. property, contractors' camps and all work in progress.

Both categories were enlisted through the Political Agent; each man was paid one rupee per day, and provided himself with a rifle and a supply of ammunition. Ammunition expended in the defence of camps was recompensed at the rate of 6 to 8 annas a round. It is certain that long after the road is forgotten, stories describing the heroic defence of this or that contractor's camp will be told in Wazir villages, and reference to the prodigious expenditure of ammunition will not be forgotten. Owing to the slow progress made in finishing off the sections, with the consequent necessity of keeping on the "protection," it was found that 10 per cent. was an insufficient allowance to cover this latter item in the estimates.

That this system of protection was a success cannot be questioned, but it is as well to realize that the degree of "protection" afforded varied considerably with the importance to the Wazir of the person or persons protected.

Throughout the work co-operation with the Political Officer and the mutual recognition of difficulties were essential. The Political Agent, Tochi—George Cunningham, an old Scottish rugger captain—was the road's greatest asset. In dealings with the local inhabitants, in disputes with contractors and in labour questions, his help, advice and tact were invaluable.

It was soon evident that progress was facilitated by constant contact between the officers and the inhabitants. The only way to get on was by cajolery, even though it entailed much talk and endless waste of time at innumerable *jirgas*.

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It was necessary to be hale-fellow-well-met with every sort of scoundrel, for though a Wazir may be persuaded or ridiculed, he cannot be driven. Many a crisis was averted, and many a situation restored by an answer coupling the claimant and his request with some utterly inane observation. The hardest struggles were with "backwoods" Wazirs, with whom there was no direct touch. These were invariably truculent, and were continually on the look out for profit from the necessities of the alignment or from robberies of cash or donkeys from contractors or coolies. However, with all their faults, they were cheery opportunists, and, by some, the road was well served.

CONSTRUCTION COMMENCED.

As has already been indicated, the road work commenced in charge of only two sapper officers, who had to start and evolve an organization literally from first principles. The "inside" organisation included the negotiations for offices and quarters in Idak Camp on the Tochi, the engagement of all clerical, drawing office and outside technical staff; the ordering of furniture, stationery, engineer stores, survey instruments and the keeping of all accounts connected with the project. Simultaneously, "outside," the location, survey, engagement of contractors, recruitment and importation of labour, setting out of work, negotiations with political authorities, engagement of protection, organisation of transport, reception of stores, siting of labourers' camps, preparation of estimates.

PLAN FOR THE OCCUPATION OF RAZMAK.

It was intended that construction should proceed without any regular military protection, until such time as a Force could be supported by mechanical transport up to Asad Khel. The Force would then proceed to Razani, where it could be supported from Asad Khel by camel transport. Meantime, the road would be completed to Razani for mechanical transport. From Razani, the "dash" on Razmak would be made, supplied by camel transport from Razani. Once established on the Razmak plateau, the Force would combine with a similar Force from South Waziristan, established at Tauda China, in a punitive expedition against Makin. The task with which all were confronted was, therefore, to construct a road suitable for M. T. for a distance of 25 miles within six working months, without military protection, at a cost considerably lower than any road in that part of the country had been constructed with protection before.

The difficulties of driving a road through the rugged spurs and waterless tracts of the frontier have many times been overcome. But in the case of the Isha-Razmak road a further difficulty

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had to be overcome, in the form of the Wazir, whose itching palm alone bespoke friendliness, with the Mahsud in the background openly unfriendly. The effect of this element was that no contractor of wealth or standing would attempt or be allowed, by the local tribesmen, to attempt the work, and the coolie, even when offered the bait of triple pay, was hard to get.

A G.E. pestered to exasperation by a contractor for payment, once said : " Have you no money of your own to pay your labourers for one day's work until measurements can be taken ? " The answer came back at once: " Would any contractor who has two annas to clink together in his pocket or who was not deep in debt to the moneylenders risk his life and his name in this forsaken country ? "

Survey of the Road.

Active survey commenced on June 1st, 1922, and, beyond the fact that the road must pass Asad Khel, in the absence of maps on which to reach a more definite decision, it might run by any route.

The survey and laying out was effected as follows :—An officer reconnaissance having fixed the ruling points, two surveyors worked down from these points with De Lisle clinometers, marking an approximate line with whitewashed *bourgies* (piles of stones). (The exception to working down from a R.P. was working up from a causeway site. Bridges form only a partial exception, since adjustment can be made in the height of the piers.) Following these came two levellers with Dumpy levels, and two computors, who laid out the grade accurately and marked it with pegs at 100-ft. intervals, covering the pegs immediately with *bourgies*. One leveller with a level, working on cross slopes, came next, whilst, finally, a surveyor followed making a plane-table sketch of the route. Each surveyor was accompanied by three or four *badraggas* and two *khalassies*.

On completion of the survey of each section the whole party returned to Headquarters to prepare estimates and drawings. This procedure was necessitated by lack of staff, but it also secured for the party a spell of comparative comfort.

Contractors.

The next problem was the procurement of contractors for the sections as they became sanctioned.

It must be understood that there was no possibility of calling for tenders for the work, since it was accepted that the work in any particular section was the privilege of the inhabitants of that section. It was obvious that these inhabitants could not do the work themselves, and so the procedure was for the Political Agent to persuade them to accept a contractor who was already acceptable

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to the M.E.S. Five per cent. of the nett bills paid to contractors was paid direct by the M.E.S. to the tribes concerned, and the contractor, if he was wise, also privately squared the local *maliks*.

The contracts specified bi-monthly payments to contractors of 75 per cent. of the work done. The bills were necessarily rough, for the officer staff was fully occupied in pushing on the work and very little was to be gained by greater accuracy, as there could be no continuity in the measurements, two days' work changing everything, though the Audit Branch would never see it. Final bills were, of course, fully measured. Idle days of labour, if justifiable, were paid at eight annas per man day, though contractors wanted more.

In order to increase their profits, especially towards the end of their work, contractors put in all manner of claims almost daily, the settlement of which was a work in itself. In spite of written contracts considerable latitude had to be allowed, as there was neither time nor staff to replace a contractor, and any such harsh action would have incensed the local inhabitants—a serious consideration in the heart of a hostile country.

Contractors recruited and imported their own labour, of which, with the exception of masons from the Punjab, quite half were trans-frontier Pathans of every conceivable kind, even Afghans. The best were Khattaks from British territory, closely followed by Hazaras and Mahsuds. Kashmiris arrived in the autumn, but they were very poor workers. Contractors arranged for the rations of their men.

In order to reduce the time and the heavy cost of protection, it was usually stipulated that a contractor should supply 1,500 men per section. Except in the ninth and last section, a three-months limit of time—excluding fourteen days for bringing up the labour and building a defensive camp—was rigorously enforced, and it was found that three miles were the most they could tackle in the time. The contractor was then paid and moved to a new section, any remaining work being polished off by the swarm of petty contractors who were always wanting a job.

The men were at first accommodated in tents, over 1,000 of which were hired from the Ordnance Department, but these were cold in winter, so, at Damdil, Jefferis made rough huts. Later on contractors found the provision of huts so profitable that they were inclined to overdo this item.

To prevent an increase of rates in sections further along the line rates for the carriage of rations were allowed—one-half for the third section and full beyond. A satisfactory system of payment was evolved on the following basis :—As 2 per mile of carriage per Rs. 100 of contractor's bill (flat rate of labour being taken at As. 12 and carriage As. 1.6 per maund mile.)

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Railway warrants for bringing up labour for the 3rd Section and beyond were given. A stipulated number should have been fixed, for, months later, it appeared that the contractor on settling-up day invariably under-paid his labour, being certain of getting a fresh lot of men up free of cost. His reasons were irrefutable—husbandry at home, for instance—and as work could not be delayed there was nothing for it but to give him a warrant for fresh labour.

Details of Construction.

The country through which the road was carried is much the same as the rest of the Frontier—hills bare and stony in the lower ranges, scrub-covered higher up and seamed by the inevitable nullahs with precipitous banks, often 120-ft. high. There were three ranges to cross: Chinikai, five miles south of the Tochi (1,400-ft. rise), Damdil (over which a way was found with a rise of a mile at 1 in 20), and the Razmak range (some 1,700-ft. rise in 6½ miles), datum levels being Tochi River, 2,100-ft.; Chinakai Pass, 3,500-ft.: Razani, 5,500-ft., Razmak Narai, 7,200-ft., and Razmak Camp, 5,800-ft. The Dizh Narai, a small pass, lay between the first two. The only rivers were the Tochi and the Khaisora (M.S. 23), the former a considerable stream, the latter usually dry. Watering places were few, viz., at Isha, Tochi, Jalair (two miles south of M.S.8), Asad Khel (M.S.14), Milogai and above Rizani (M.S.27), Naghar, in a parallel nullah north of Damdil, was not discovered till August.

Between the ranges there lay most useful stretches of high level plains; beyond the Rocha (M.S.18) these "raghzas" were obviously water-formed terraces, those towards Razani being on the heavy grade of about 1 in 18.

The sub-soil was usually hard conglomerate (shale in the Shini basin, 50 per cent. earth on Alexandra Ridge) with rock strata lying at every conceivable angle and full of boulders, many of considerable size. Some of this conglomerate was practically natural concrete, notably in the last mile to the Rocha nullah. Much hard rock (usually limestone) occurred in wide belts in all side cuttings, the longest being in the last mile to the Tochi, and the first mile of the 8th section. Shaly rock, both red and black, was found in all side cuttings. Beyond Razmak Narai the ground was alluvial overlying conglomerate.

Side slopes varied from 1/2 to 1/1. The strike of the strata was favourable for road alignment on the east and south faces of the ridges up to Pariat (M.S.28), when it changed to west, admirably suiting the military requirements, which, for ease of piquetting, required that the road should be taken up Alexandra Ridge.

The method of carrying out the work in hill country, where diversions were not possible, was roughly as follows:—After the level pegs had been laid out at the grade on the cutting line, the

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contractor dug in the ordered distance, following the curves of the hill side, and made only the essential culverts on straight alignments and rough temporary culverts at the re-entrants. The permanent culverts at these points were made later outside the road, often when traffic was running. Soling was often laid as soon as the width of the cutting was 15-ft. This, when well blinded with shale, allowed for one way traffic, meanwhile the contractor completed the further cutting, side drains and catch-water drains. Normally, of course, the road was cut at once full width, in order to simplify measuring and to better the grade. At times consolidation had to be done under traffic, but this was awkward and led to claims for idle labour when convoys were passing. On plain sections the road could be made in the regular manner, traffic using a diversion.

Metal was, if possible, broken and stacked on the soling, this being the speediest and easiest way for measuring; otherwise it was broken above the road and thrown down, but this introduced undesirable dirt. The method of metalling half the road and excavating the other half later also had the disadvantage of making the road dirty, as the coolies would not use wheelbarrows, and, working three on a spade, shovelled the earth in stages across the road.

Zigzags, unfortunately, had to be introduced on the later sections. If well laid out they offer little hindrance to H.M.T.; the points to look for being:—(*a*) Choose a knob or a flattened place on a ridge, giving a really good turning circle, and scheme the road down to it; (*b*) take the road round level, if possible; (*c*) give double the super-elevation you think necessary to allow for settlement, since revetment walling will invariably be necessary, with a portion of the road on filling; (*d*) largely increase the super-elevation on the outer berm—some fool is sure to think it is Brooklands, and an extra "saucer" will save him; (*e*) remove all high ground from inside the zigzag—it will go in the filling; (*f*) make the corner 50 per cent. wider than the road and give a low strong centre wall to separate up-going from down-going traffic; (*g*) be very careful over drainage, make stone drains of large size round the inside of the corner, or heavy rain will cut right across it.

Culverts were, whenever possible, C.G.I. tubes singly or in pairs, 2¼ or 3-ft. diameter, well let down into the ground, and laid at a slope of 1 in 7. At first they were cased in lime concrete, but this took time, so that later, when the completion of the road became urgent, the tubes were merely surrounded by a good layer of hand-packed stone—as was done in 1897 on the Malakand road and was still perfect in 1915.

Larger waterways were crossed by R.C.C. slab culverts. Water openings were calculated by Colonel Paul's larger formula and

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withstood a cloud-burst. The Paitopangi Bridge above Razani was R.S.J. on stone piers with R.C.C. decking.

The Tochi Causeway was built, according to the N.W.F.P. Civil Specification, with shallow drop walls of stone in lime, the two top courses being in cement (D.S. drop wall only 3-ft. 6-ins.), depending entirely on a water cushion apron formed of six rows of C.C. slabs, 6-ft. x 6-ft. x 6-ins., wired together both ways by two 1-in. steel ropes. Cement being short, this apron was actually made of boulder stone in 6-in. mesh telegraph wire crates, 2-ft. thick and 12-ft. wide. A 6-in. floor reinforced with telegraph wire was soon added, defects owing to too rapid construction having become evident. This causeway stood well, but constant repairs were necessary to the apron.

This design had obviously insufficient strength to withstand the horizontal pressure of a moving bed, and experiments were made later by giving toe walls 2½-ft. high 20-ft. down stream, the top being level with the footing of the D.S. walls, and strutting across with 6-in. x 6-in. R.C.C. beams 6-ft. apart, one additional beam in each case being given longitudinally. The spaces between the beams were filled in with 2-ft. hand-packed quarried stone and wired, and the excavations filled in level. Floods never scoured more than 4-ft. down the aprons, and at this distance semi-natural water cushions were formed. Four causeways were made to this design, and all were satisfactory, representing an undoubted economy in cement and cost; the only possible objection being the necessity of good workmen and first-class supervision.

The only failure occurred on the 20° skew Lukki Khula Causeway, where a big flood caught the work before the spoil banks had been cleared. This 3-ft. flood, coming down a nullah sloping at 1 in 50, rushed through a narrow opening cleared in the spoil bank and carried away 120-ft. of the causeway, although the D.S. wall was 8½-ft. deep.

A causeway must be sited at the true nullah level, which can only be found by taking a long section of the bed from one mile above to one mile below the site, plotting this on a large scale, drawing in the mean slope of the nullah and giving the causeway the level at which this mean slope crosses the site. It sometimes helps to give the causeway a side slope of 1 in 50.

In shingle nullahs protection of the banks was found to be best effected by stone "bunds," which, run out perpendicularly to the bank, or slightly up stream, allowed the bank to silt up. These bunds were constructed either of boulders in a wire crate, or after the country pattern, of boulders laid with layers of brushwood in between. The latter method, besides being the cheaper, usually lasted longer, since the wire on the former kind was generally stolen.

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WATER SUPPLY.

The water supply at Tal came from a shallow well near the Tochi, the water being pumped through a 2-inch rising main to a 16,000-gallon concrete reservoir in Tal Camp, a Worthington pump and portable boiler being installed alongside the well.

The supply of Asad Khel, Damdil, Dizh Narai, and Chinakai was finally effected from a well at Asad Khel. Although it was at first intended to use the Jalair springs, it was afterwards found best to pump from the wells at Asad Khel, which tapped the certain supply of the Khaisora River, to a reservoir of 22,800 gallons capacity on a hill behind the camp. From here a gravity supply was piped to reservoirs at Asad Khel Camp (5,000 gallons), Damdil (4,300 gallons), Dizh (9,750 gallons) and Chinakai (16,500 gallons).

The plant at Asad Khel consisted of two 12 h.p. vertical boilers supplying two Worthington two-throw pumps, the whole being housed in a defensive tower of stone. The rising main was 4-in. diam. W.I. pipe, as was the delivery as far as Damdil, with 2-in. diam., reducing to 1½-in., beyond. Above Asad Khel it had been hoped to tap a supply at the Sura Mela Algad, but the determined hostility of the villagers made it necessary to abandon the scheme. On the discovery of a *korez** at Tamre Oba, plant, similar to that at Asad Khel, was put in and the site proved to be better than that originally intended. Much reconnaissance and trial digging was done around Razani before a spring was discovered some three miles away under Shin Dhur. This, when built up, and defended by a picquet tower, provided a splendid gravity supply, piped to the camp by a 2-in. pipe.

A good source of supply was found for Razmak Camp in a spring some three miles to the west of the camp site.

Excluding the head works and the defensive tower, the work, which also comprised two 25,000 gallon reservoirs, was carried out by the 13th Co. S. & M. This scheme proved very expensive owing to the amount of "compensation" which had to be paid to the locals and to the cost of transporting pipes to Razmak before the 8th Section was available for transport.

All pipe lines were buried 2-ft., except at Damdil, and at this depth withstood frost, whilst as an additional precaution leaks were arranged at all taps.

DESCRIPTION OF THE EARLY ROAD SECTIONS.

The new road takes off from the very fine Tochi road, which was built in 1919 and 1920, a few yards west of Isha, and follows an old track to the River Tochi, which is the first obstacle. This was the obvious point to end the first section.

* A "korez" is an ancient underground masonry channel laid at a small slope, tapping a deep-seated spring by gravity flow.

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On reaching this point the keenness of the Survey party evaporated, but Jefferis, by personally taking charge, made the excellent rate of 1½ miles per day, and by July 18th had carried the trace beyond Asad Khel.

Many days were spent in aligning the first section satisfactorily to both bridge and causeway sites. The former was fixed at the upper end of a long sloping solid rock bank, 100-ft. high, where a road would have been too costly. The causeway had to be made upstream of the bridge site, and no amount of laying out could evolve any better arrangement than to make a steep, 1 in 15, approach to it, trusting that funds would be available later for the bridge.

The first sod was cut on July 11th, 1922, with considerable *tamasha*, and work started in earnest on July 14th.

The contractor gave much trouble, and this section—of great importance, since the Force Dump was to be formed at Tal, beyond the Tochi—was only finished in time by much driving, fining, and by putting on outside labour.

The Tochi causeway was constructed by Bradney's 13th Co. S. & M., which was assisted later by the 32nd and 34th Sikh Pioneers.

On the south bank of the Tochi the road rises on an embankment and bends round below the old militia post at Tal. This post had been repaired by the Political Agent to form a *khassadar* headquarters, and subsequently camps had been built at Jalair and Asad Khel for a similar purpose. These posts served as refuges, at which officers working up the line could stay by night.

The road rises evenly to the Chinakai Pass, in soft shale, which became a species of porridge in the rains and again impressed the necessity for ample catchwater drains and culverts.

In July Jefferis went on a month's leave as a result of fever and frontier sores. He was replaced by Dickson, who was lent from the 13th Co. S. & M.

Early in August, survey was allowed beyond Asad Khel, and thereupon commenced endless difficulties engineered by the occupants of this village.

The ground beyond the Rocha Algad had not looked promising in earlier reconnaissances, however, as a result of ignoring the misrepresentations of the Asad Khel villagers, terraces and a three-mile plain were discovered on the left bank of the Khaisora river, which, when linked up, proved ideal.

This alignment avoided completely the large burial ground of Khani Ziarat on the right bank, which the Asad Khel villagers had been so anxious to drag in as a reason for compensation. The Rocha and Tamre Oba nullahs took a lot of defeating, and several zigzags and hairpins were of necessity included, in order to negotiate

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the almost sheer sides of the *algads* down to the Khaisora river bed.

At one period progress was made against the local villagers, only after yard by yard argument, until, raising an old political grievance, they declared that they would shoot anyone proceeding further. In spite of all this intimidation, Dickson went forward with the survey party and the native political, and after a couple of miserable nights in Wazir villages completed the survey to Milogai, and was fired on as he returned. The Political Agent finally settled the dispute by the exercise of much tact, and by the end of August contractors had been found for the work up to Asad Khel.

DIFFICULTIES OF THE UNDERTAKING.

It is profitable at this point to try to gain some idea of the conditions under which all this work was being tackled.

You are asked to picture the scene at the office at Idak, where, for some weeks, one solitary man struggled with the "inside" or paper work, supported only by a hastily gathered staff of *babus*.

Under the verandah, on the ground, and on forms, squat, sit and lie all manner of unwashed bearded men. Some have Snider rifles and wonderful cartridge belts. There is a strong scent of goat-*cum*-camel in the atmosphere, which rises quickly, as the shade temperature is hovering around 110 degrees. Some are asleep, others are expectorating, many are declaiming. Save for those asleep, a kind of wave passes over the multitude as a strange *sahib* reaches the entrance to the office, and some deign to rise as he approaches. (They rise much quicker when it's the *sahib* who makes their payments.)

In the middle of a concrete floor, bounded by whitewashed walls, which are covered with blue prints, sits a harassed officer in shirt and shorts, with pipe in mouth. He is sitting at a desk littered with papers and plans. At his side is another table covered with trays, catalogues and maps. A murderous-looking villain stands at his side, and is in process of making a long oration in Pushtu.

Sit down over there, you won't be under the only fan, but we haven't really got the office properly fixed up yet—not much time really, as there's no E. & M. Officer here yet—and the weekly progress report is due to be posted to Simla to-day, and Mir Jani, the contractor, is screaming for more work to be set out, and there are about thirty lorries waiting outside for instructions as to where to dump their loads—but sit down, and look around.

You will probably gather the trend of the conversation. It is obvious that the gentleman in filthy white (it has been computed by some sportsman that a Wazir spends eightpence a year on clothes and nothing on washing) will not be pacified—he is gesticulat-

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ing now, and although you cannot understand a word, it is clear that he is a ruined man morally, financially and in every other way, and you wonder at the " spirit " which makes him hang on to life so long. The conversation goes on crescendo until finally a climax is reached. A *chit* is written—you catch the word accountant—and the murderous gentleman regains in a second his moral and financial status—breathes a prayer for longevity and prosperity on the head of the harassed officer, and salaaming, takes his departure behind the flapping spring doors.

A scuffle ensues outside and he is immediately replaced by another villain, who is well into his tale of woe before you have time to take breath. He is a *badragga*, who has fought a hand-to-hand fight to preserve the labour camp at Tal for some nights now. His expenditure in ammunition has been prodigious, and he wants it replaced, or better still, money in lieu, at once.

Meanwhile, the lorries have dumped all their gear where no one wants it, several camels have rushed the by-pass gate with corrugated iron drain tubes dragging behind them, the telephone has rung eight times, which has meant the harassed officer listening to the story of the murderous villain *re* " cartouces " all over again, with additions as he warmed to his work. The draughtsman has hovered in the portals with miles of longitudinal sections—tea has arrived and gone cold long ago, *chaprassis* have continued to pile up files on the table, and now have recourse to the floor. The Accountant has intimated that the Audit Branch require the whole of the last five months' accounts recast in a completely new form. A more respectable looking gentleman announces that he has 4,000 coolies waiting at Campbellpur railway station, each of whom he is supporting out of his own pocket at an exorbitant sum per diem, and please can he have railway warrants for the lot ?

Well, you have seen a very typical day. This *tamasha* goes on week after week.

The only respite from scenes such as these is the open road. Riding and walking over miles of rough hillside, with a De Lisle clinometer, locating the road line, always under a burning sun, and " protected " by an array of prize cut-throats.

Another officer was living " up the road " alone. He was out all the hours of daylight on foot, tramping all over the place, discovering a suitable line for the road, checking it roughly with a clinometer, and encouraging the timid survey party which was naturally in the forefront ; further back, cursing slow and lazy contractors, being all things to all men with the *badragga* escort, which held his life in their hands, at a rupee a day ; finally, coming back day after day to the shelter of a torn 80-lb. tent, to eat an enormous meal, occasionally to send back a crumpled note

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asking for " more drink when you next come up," still less often to come himself into Idak—the metropolis—for a night.

And far into the night, by the light of a hurricane lamp, on an upturned box, he would scribble the data on which an " approximate " estimate might be made for a section, which estimate would be knocked into some sort of shape by the " head office," and, finally, be landed in Simla for microscopic examination, criticism and return.

CONTINUATION OF THE PROJECT.

At the end of August, Col. W. H. Evans, the Deputy Engineer-in-Chief, arrived to inspect the progress. He at once saw that the job was very understaffed, particularly as active operations were imminent, requiring much additional work in preparing camps, permanent piquets, and a reliable water supply. As a direct result of his visit additional officers began to arrive, and the work began to receive the supervision that its magnitude and the circumstances demanded.

The Asad Khel *maliks* soon found a fresh source of claim, and a considerable dispute arose over the use of an essential saddle close to their village. This trouble was settled by the improvement of certain portions of their main irrigation channel.

In September the Signals commenced the construction of a permanent air line along the road under Captain T. J. Evans, a most fearless and capable officer.

At this time the section which gave most trouble was 3B. The original contractor failed to live up to his wonderful *chits*, and, as reliable contractors were hard to come by, the work had been carried on by a daily labour contractor, who could never muster sufficient men. With the providential arrival of the Ghilzais from Afghanistan in November the situation was saved. They took orders for 5,000 men—double the requirements—who most unexpectedly arrived, causing considerable congestion.

Lengths of road were given to their contractors at the rate of 100 r. ft. per 25 men. Four thousand five hundred men were camped at Damdil, and Jefferis and his excellent S.D.O., Rahmatullah, moved there to settle the almost hourly disputes of such a heterogeneous mixture. Work was concentrated on hill portions, since, these vital links finished, vanettes could always traverse the plains stretches on diversions.

Meantime Glazebrook had taken charge of the Engineer Store Park at Idak, which was growing in size, fed by lorries from Bannu. Endless streams of carts, camels, and donkeys carried the gear forward to Tal and beyond. Four road rollers had been got across the River Tochi for the second section, and others arrived from all parts of India, until there were no less than twenty, all in varying

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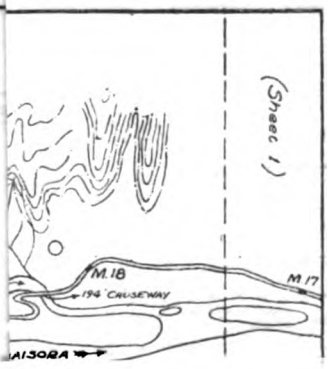
(Sheet 2)



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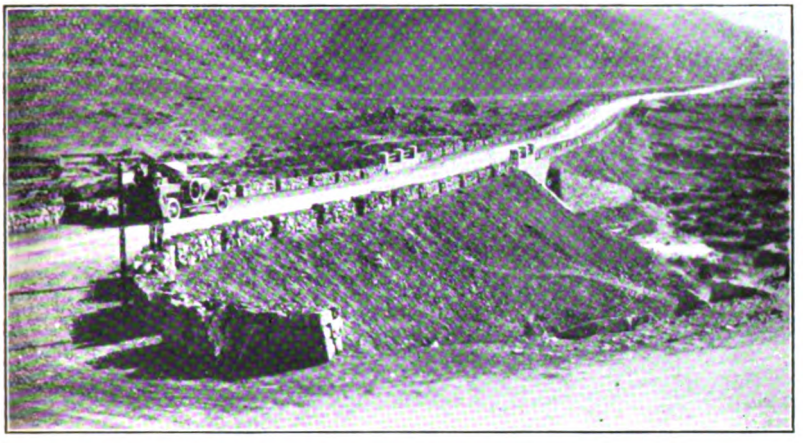
ISHA RAZMAK ROAD.



Section 1. The commencement of the Road at Isha.

Section 2. Tochi Causeway looking towards Tal

Section 2. A corner above Tal.

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Section 3A. View from Dizh Narai looking North.

Section 3B. View down Damdil Narai looking East

Section 3C. Lakki Kula Algad.

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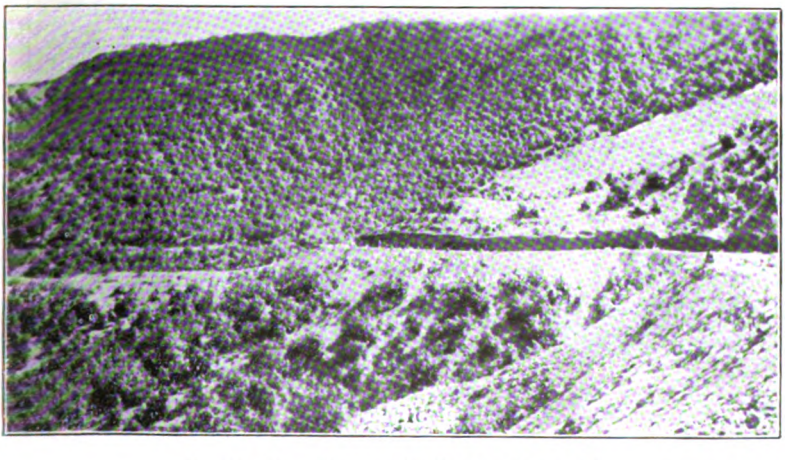
Section 5. Near Tamre Oba.

Section 8. Lower portion looking South.



Section 8. From the Razmak Narai.

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Khaisora Zigzag showing centre dividing wall.

A typical Jirga.

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states of repair, and of different makes, rendering the acquisition of spare parts extremely difficult. Darling, the E. & M. Officer, was kept very busy with this heterogeneous collection. Two rollers were retained to provide spare parts for some of the others, but even so, age and the evil machinations of the drivers, successfully kept several out of work. Matters were improved by a system of bonuses to the roller crews, tempered by fines for avoidable stoppages.

A cleverly staged Mahsud raid at Asad Khel caused a loss of 160 donkeys to the contractor on the fourth section. Evans, of the Signals, rode through the ambush seeing nothing, but Dickson, inspecting work, had to run for it, and the Mahsuds kept up a barrage for an hour to get the booty clear away. This raid eventually cost the Government Rs. 9,600 in compensation.

In November Colonel C. H. Haswell came to live at Idak as C.R.E. All along there had been great need of someone to fight the " superior " battles and to give practical orders and helpful counsel in the many perplexities.

Owing to lack of water, most of the road from Chinakai to Damdil Narai was consolidated dry with soft shale chippings. Rain during, and vanettes after, consolidation, naturally helped matters, but that part of the road became very slippery in rain. This construction was found to last well even under heavy M.T., which was allowed over it after the vanettes had been running for a month.

By November 16th the 3rd and 5th Coys. K.G.O. S. & M., 20th and 21st Coys. Royal Bombay S. & M., 13th Co. Q.V.O. S. & M., together with the 32nd and 34th Sikh Pioneers, were all at Tal and at work on various portions of the road. No. 5 Coy., under Greenwood, improved a difficult corner a mile south of Tal by means of some very fine dry stone revetment walling.

Dickson had now practically completed the earthwork on the fourth and fifth sections and the ascent of the Girdai Raghza, but the stretch behind Khani Ziarat graveyard was untouched. There was great trouble here, as the locals alleged that the thorny acacias on the hillside alignment behind it were as sacred as the olives in the graveyard itself. After three heated *jirgahs*, and the slaying of some goats to propitiate the spirits, work was allowed to proceed, but progress was hopelessly slow.

The cause of the anxiety to get this portion completed was the fear of spates in the Khaisora River, the bed of which was at that time the only route available for the vanettes which would supply Asad Khel when the troops moved there. Finally, an inferior alignment, lying farther back, was arranged only just in time to avoid the floods.

The progress of the work received a very severe blow on December 12th, 1922, by the murder of Dickson. He should have come down to Idak that day, but, having made arrangements for guards,

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etc., he was allowed first to get data for the seventh section estimate, of which the reconnaissance had already been made. On his return he somewhat outstripped his guards, and fell riddled with bullets, while his assistant, Lieut. Bromhead, 32nd Sikh Pioneers, had a miraculous escape at his side.

Throughout Dickson had done amazingly. He was out daily on his long charge, with little or no protection, and only his dauntless courage could have carried him over the countless difficulties, dangers, and discomforts he had faced. Long after, it was said that the Mahsuds had vowed to get the three original officers on the road, since it was due to their efforts that the security of the Mahsuds was threatened. Greatly to their credit, the staff at Tamre Oba did not lose confidence, and the S.D.O.—one Abdur Rahman, a permanent M.E.S. subordinate,—carried on the work, but as a result of Dickson's murder, work beyond Tamre Oba was forbidden pending the arrival of regular troops.

The 5th Brigade, which had reached Tal on December 15th, proceeded to Asad Khel the next day, and on the 17th the first vanette convoy ran from Tal to supply them. Early in January the 7th Brigade, designated for the Makin operations, advanced through the 5th Brigade to Razani.

From Razani, the road had to rise 1,400-ft. or so to the Razmak *narai*—the bulk of the way through thick vegetation of holly oak and fir. Jefferis, profiting by the protection afforded by a reconnaissance by the 7th Brigade on to the Razmak plateau. reconnoitred, in deep snow, the alignment of this eighth section, The trace of this section was not cut when the composite 7th Brigade made its march on to the plateau in a snowstorm, and only a small and very steep ice-covered path had been cut for the troops and camels to follow. How this march was accomplished in a blizzard in January, 1923, and what befel the 7th Brigade before it finally established itself in a wonderfully sited camp near the Shuran Algad, on the grassy slopes running down to the Tauda China stream, is another story. Suffice it to say that the true soldier struck the canvas in Lazani before the rain came, so that there was not their weight wet to carry—also that much mud, sweat, and curses pushed the last camel over the slippery *narai* on to the "promised land" at about eight p.m.—long after dark.

Vanettes were now running through to Razani, although improvements and final touches were still being made behind.

The alignment of the 9th section presented no natural difficulties, but, owing to trouble with contractors, it took five months to complete, and vanettes did not get to Razmak camp until June 15th. It must, however, be stated that there was no urgency for this section, as brigade stores were being sent up by camel convoy.

The next item of note was the erosion, for the second time, of

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the right bank of the Tochi adjoining the causeway. To combat this a heavy bell bund, formed of boulders in wire crates, was run out from the bank and upstream. A wired stone boulder apron was given on both sides. This bund had immediate effect, the dead-water area silting up 6-ft. in two floods, inducing secondary shoals up-stream, which diverted the stream away from the right bank altogether.

The eighth section was well in hand, and much valuable work had been done on it by various S. & M. companies. Both the 20th and 21st Coys. had worked on the three-span girder bridge across the Paitopangi, whilst Greenwood's No. 5 Coy. had made another fine retaining wall round a zigzag. The work can almost be described as monolithic, since boulders, requiring 30 sappers to bring them on to the site, were built in.

At the end of March all companies, except the 13th and 20th, left for the Takki Zam. The 13th Coy., belonging to the 7th Brigade at Razmak, worked on water supply for Razmak Camp, whilst the 20th Coy. remained to finish work in the eighth section. The road was finally opened to heavy M.T. on August 10th, 1923, thirteen months after the cutting of the first sod at Isha, though vanette convoys ran to Razmak from the 12th of June.

A cause for congratulation was provided by the fact of the accounts panning out with a small saving, in spite of many heavy unforeseen items, such as the "entertainment of *jirgas*" (no detail given) ranging from Rs. 5,000 to Rs. 10,000; extra *badraggas* employed to look after labour on operation works, with their camp expenses, water, ration carriage, etc.; extra rates and bonuses for completing vital links quickly; compensation to contractors for losses; and the cost of cutting so-called "trees" along the alignment.

Casualties, in addition to Dickson's murder, included eight of the M.E.S. staff and some 40 coolies killed. In the coolie camps between Razmak Narai and Pariat, where during the winter for two months there was always a foot of snow on the ground, 50 coolies died of pneumonia due to exposure, and at no time was it usual for a returning camel convoy to pass without bringing at least one white covered *charpoy* lashed to a camel's back bearing some corpse back to the plains.

To the fine work and devotion of the officers and staff, and also of the Sappers and Miners and Pioneers, all too briefly mentioned, was due the successful conclusion of the work.

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SOME UNEXPECTED PROBLEMS WORKED OUT BY THE ROYAL ENGINEERS DURING THE 1914-18 *WAR.*

A Lecture delivered at the S.M.E. Chatham, on 12th March, 1925, by MAJOR-GENERAL W. H. GREY, C.B., C.M.G., D.S.O.

When accepting the invitation to lecture I informed your Commandant that I am not an engineer and, therefore, any remarks I may make concerning engineering work and its results can only be taken as applying to management and control and not to technical and scientific work for which scientific training and practical experience are essential.

Amongst the unexpected problems the Royal Engineers were called upon to solve during the 1914-1918 war were two transport problems. The first big one I was connected with was the re-organisation of transport services on the Tigris and Euphrates in Mesopotamia. Some time after the fall of Kut the War Office decided to take a greater share of responsibility for the forces in Mesopotamia, and in July, 1916, I was sent out to report upon the Water Transport service then being done by the Royal Indian Marine. The War Office, on receiving my report, instructed me to take on the work myself and carry out my own recommendations.

During an exchange of cables with the War Office, London, I agreed to take on the responsibility for the re-organisation of the Port and River transport if the War Office would agree to convert the Royal Indian Marine services in Mesopotamia into Royal Engineer services by giving the Royal Indian Marine officers temporary commissions in the Royal Engineers and the temporary Royal Indian Marine officers, temporary General Service commissions, also to transfer control to London instead of to India.

Officers of the Royal Indian Marine hold no commissions, and, although their status in the Army and Navy had never been questioned, I believe it is a fact that legally they ranked as camp followers with the Army, and so far as the International Sea Law was concerned if a Royal Indian Marine ship had fired at an enemy ship the Royal Indian Marine ship's act would be that of a pirate. When the War Office and Indian Government had agreed that the Royal Indian Marine officers should transfer to the Royal Engineers, I informed the officers that if any of them did not wish to remain in Mesopotamia under the new conditions they could go back to the Royal Indian Marine in India; only one officer elected to return to India, and he asked permission to reconsider his decision the day

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before he sailed. A man could not wish to meet a finer set of men or more loyal men than the Royal Indian Marine officers who served with me in Mesopotamia. The work done in Mesopotamia under the control and in the name of the Royal Engineers consisted of building wharves, building a dockyard, workshop, slipways, barges and river steamers and doing all the river transport for the Army and Civil authorities, a great deal of river conservancy works and water supplies. Practically the port of Basrah was constructed.

Colonel Symons, the present C.R.E. Mesopotamia, wrote to me the other day and said that almost every civilised work in Mesopotamia to-day had been done by the British Army—water supplies, electric light plant, ports and railways. He is not a man to exaggerate, and the British Army in this case means the Royal Engineers.

Before the Royal Engineers undertook the work there was no wharf at Busrah alongside which a ship could lie, except the old German Baghdad Railway wharf, where there was accommodation for one vessel. In a few months accommodation for 10 ocean steamers to lie alongside wharves was put up, slipways capable of taking the heaviest river steamers were built, repair workshops and a large wet basin constructed. One hundred 300-ton barges were built and numerous river steamers constructed. Workshops and wharves were made up river at Amara and Baghdad. Permanent floating bridges at Amara and Baghdad were built, and, when the advance to Baghdad commenced, 6 months after the Royal Engineers took over the river transport, there was not the slightest hitch and the work was done to the satisfaction of General Maude.

From information gained whilst doing the work as Director of Inland Water Transport in Mesopotamia I came to the conclusion that the failure in Mesopotamia in '15 and '16 was due to ignorance of conditions in the country, on the river, and of the supplies possible to obtain in India and Burmah suitable for the Tigris and Euphrates. When I was sent to Mesopotamia in 1916 I was informed that India had been combed dry of all craft suitable for use on the Tigris. I was informed that for half a year the draught of water from Basrah to Baghdad was only 3′ 6″, and that the current at times and in places over long stretches of river ran up to 6 knots per hour. I was informed that the only site suitable for constructing barges and ships was at Abadan, below Basrah, where land was difficult to obtain. I found in practice that the current was about 2 knots per hour, and only around various bends at flood time was a current of more than 3 knots per hour ever experienced and then only for a day or so, that by shewing the channels in the river by proper buoys and survey marks vessels drawing 5 feet could get up to Baghdad practically all the year round. Think what that means, a difference of 40% in the carrying capacity of a fleet. When I went up river the first time to make my report there was not a single buoy or survey

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mark on the Tigris proper from the junction of the Tigris with the Euphrates to the trenches at Sheik Said near Kut, 250 miles. All vessels used to run aground and lose days every voyage on unmarked sand banks, and in consequence the river service was only doing half the work it should have done.

I found that by sending my own officers to India materials and river steamers from the Ganges and from Burmah, most suitable for Mesopotamia, could be obtained, in fact, after we captured Baghdad I obtained permission from General Maude to send an officer, Colonel Ratsey, of the famous family of Ratsey's, the sailmakers of the Isle of Wight, to India and he was able to get 10 magnificent river steamers, each of them capable of carrying from 500 to 1,000 men. These vessels came round India and were eventually used between Basrah and Baghdad.

I found that practically the whole country from Basrah to Baghdad, 500 miles, was suitable for building yards for constructing barges and river boats. Slipways for taking the heaviest river vessels were built, excavations and filling up of land for the slips was done by hand labour and the excavation for a wet basin at the back of the dockyard, together with its connecting river channel, was also done by hand labour owing to no machinery being available. The labour used consisted of part of an Egyptian Labour Battalion and Indian labourers recruited as lascars for work on the river steamers; there being not sufficient river steamers requiring the services of the lascars they were persuaded to do the necessary mud shifting.

The various specimens of river steamers and barges shown on the screen will give you a very good idea of the fact that for river work almost any kind of vessel not exceeding the necessary draught can be used. The idea that special vessels have to be built for rivers like the Tigris and the Euphrates is an exploded one. One of the vessels shown is the old Thames steamer "Brunel," one of the so-called penny steamboats which used to run from Richmond down the Thames. A number of the vessels, including the "Brunel," were sent out to Mesopotamia from England under their own steam, although they only drew 3′ 6″ to 4′ of water. The Admiralty would not take responsibility for sending the vessels, and they were manned by Royal Engineer enlisted men and flew the Royal Engineer flag. They were not entitled to fly the White Ensign and were not merchant vessels. As the Royal Engineer Flag was not known to the Italian and French Patrol vessels in the Mediterranean the vessels caused something of a sensation when they passed through.

The second problem was due to the German Submarine campaign, which caused the British Government to decide to send troops and supplies for the Mediterranean and Eastern theatres of war through France and Italy. The best port the French Government could place at the disposal of the British Government was that of Cherbourg,

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and at this port only the small harbour, really a harbour suitable for coasting vessels, was available. The Great Naval harbour was kept by the French for their own naval purposes. Ordinary necessary constructional work, railways, warehouses, and camp, was done partly by coloured South African Labour battalions and partly by contract with French contractors. The plans were drawn up by the War Office and there was little or no difficulty or trouble in getting them completed. Rest camps were formed at various intervals between Cherbourg and Taranto, as it was not thought advisable from a health point of view that troops should travel in trains for such a long distance without having opportunities for exercise and a general clean up. There were difficulties in obtaining building materials at the various camps and *halte repas* places. At one camp in the middle of Italy the officer in charge found material enough to write a book on his experiences. The main difficulty as regards accommodation for troops was at Taranto. I was sent along the Cherbourg-Taranto route to inspect it, on my return from Mesopotamia in July, 1917, and in my report I referred to the conditions at Taranto, where there were hundreds of men without any tents, and there was absolutely no accommodation for officers, who were arriving by various steamers, and were told at Salonika and Egypt that as soon as they arrived in Taranto they would be put on the international sleeping carriages straight through to Cherbourg; consequently they did not bring their kit, and one steamer arriving with about 200 officers presented a difficult problem to the Camp Commandant who had no funds available to purchase any necessary articles for the table, such as cutlery, chairs, etc.

I returned to London and advised the War Office to take away from G.H.Q. the control of the Cherbourg-Taranto Route, because I was convinced that any officer who became responsible for the work, and had to depend upon G.H.Q., France, for supplies of men and materials, would find it impossible to get the work done in a reasonable time, and if attempts were made to use the line under existing conditions serious trouble would ensue. The officers of the G.H.Q., France, had more than enough work and worry nearby and could not be expected to worry much about a place 2,000 miles away. I sent in my report one Friday evening and at eleven o'clock next day, Saturday, the War Cabinet agreed to transfer the Mediterranean Lines of Communication from G.H.Q. Branch to direct War Office control, and I was told to take charge of the organisation abroad; my headquarters would be at Lyons. Lyons is in the middle of France and is not on the direct road from Cherbourg to Taranto, but it was thought that headquarters in Paris might interfere with the prestige of others handling the war in France. However, in about a week I was able to convince the War Office that if any good was to be done at all,

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Paris had to be the headquarters. All arrangements for trains had to be agreed to by the French, and Paris was the best place where one could get into communication with both the French and British War Offices, also when necessary with G.H.Q., France.

One of the troubles at Taranto was malaria, and this had to be attacked by insisting upon mosquito nets being issued and the area round the camp properly drained. Eventually Taranto was made into almost a model camp, but it was a very worrying job. The transport of troop trains the whole length of Italy and France could only be carried out with the goodwill of the French and Italian officials and people in the districts near the rest camps. The only serious trouble occurred with some of the coloured troops who were sent to Taranto to labour some months after I had severed my connection with the route, but in every other way the experiment of using the land line, instead of sending supplies and men by sea, was a success, and if the war had continued it would have been found to have been the only method by which it would have been possible to keep the Eastern Armies supplied without running unfair risks. The cost of transporting men and materials by the line was very small. Real constructional work did not commence until July, 1917, yet in October, 1917, the line was actually transporting more cargo than ships were available to take at Taranto.

The original War Office scheme for the construction of wharves at Taranto had to be altered owing to the difficulties of obtaining materials, and it was decided to build barge jetties and wharves instead of a wharf suitable for ocean going steamers. The general idea that vessels can always be loaded more quickly when they are lying alongside a wharf than when in midstream and loading from barges is not always correct. It is possible that loading by man power may be at times more expeditious, also, if ships have plenty of derricks and can load from barges on both sides, it is possible to load more quickly than on one side of a quay. The decision to build only lighter wharves was taken after due consideration of the difficulties of obtaining machinery, and the question of being in a position to load more than one steamer at a time.

One of the great difficulties in constructional work at Taranto was that of obtaining material, particularly timber. The Italian General Staff sent down a General of engineers to investigate our requirements, and when it was explained to him the amount of air space considered necessary for the accommodation of the British Tommy, when making estimates for huts, he was horrified. He said that in the Italian Army the huts used by the British would be made to hold just double the number of men we put into them, as beds would be built up in tiers, one above the other, as on board ship. This idea does seem to me to be a sensible one for putting

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into force at any rest camp where a man has to be one or two days at a time, but the medical authorities are all against it, and housing accommodation at any British camp becomes, in consequence, a very expensive item.

Although the Cherbourg-Taranto Line of communication represented a problem not thought possible in pre-war times the whole problem was really worked out by officials in the War Office, and to them more than anyone else is due the credit of the work. Their plans both for construction and time tables for the trains were practically worked to. The alterations in constructional work necessary owing to various changes of plan at different times were all submitted to the War Office first for approval, and the advantage of being able to consult with the War Office officials over any difficulties cannot be too highly appreciated. General Mance was really responsible for the War Office control and carrying out of the Cherbourg-Taranto scheme, and I cannot call to mind a single instance of a request for assistance not receiving prompt attention. Sir Guy Granet, who was Director General of Movements and Railways, was always sympathetic, gave one every support, and one was not worried over petty affairs. My experience on the Cherbourg-Taranto route was that, provided one kept the War Office fully informed of progress and difficulties, one received every assistance and support both with advice and materials.

As an instance of the difficulties of working in Allied countries I should like to point out that on the Cherbourg-Taranto route it was necessary, for a time, to arrange for the troops to change trains at Modane, the frontier station on the Italian-French frontier, because the Italians did not like their waggons being run into France, and the French did not like their waggons being run into Italy. They both said that they never got them back if once they crossed the frontier. A certain number of officers and nurses travelling over the route went by the ordinary passenger train, which followed the route, Genoa, Rome, Naples, Taranto, whilst troop trains followed the East Coast Route, Genoa, Bologna, Ancona, Bari, Brindisi, Taranto. The traffic via Rome was very annoying to the Italians, as it meant that the limited accommodation in their reduced passenger train service during the war was, so far as they were concerned, further reduced through the increased British traffic. Many instances of officers and nurses causing trouble with Italian railway officials by endeavouring to retain more than one seat in a compartment were brought to my notice, and at one time it was seriously considered issuing orders to stop officers and nurses travelling by the ordinary passenger train. Fortunately, by the help of having R.T.O's at the principal Italian stations, supported with the moral support of the military police, the nuisance was to a great extent mitigated, but there are in the files of the Embassy in Rome some

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rather amusing complaints of the conduct of some of the British passengers. Of the many thousands of officers and men who travelled by the troop trains we had practically no complaints.

Generally speaking, communication between the Navy and the Mediterranean Lines of Communication officers was always most cordial, and at Taranto, where we had quite a large naval force, the work could not at the commencement have been properly carried out without a great deal of assistance from the Admiral in Command.

To those who may have to do similar work to that I had, I would say: If your work is in an Allied country you will find that all the things you want for your work will also be the very things required by the Allied Army, which naturally has first call, and you will get more by doing things unofficially than is at all possible through official channels.

A matter of most importance in connection with expenditure is the keeping of accounts for any work undertaken. Each officer in charge of work must necessarily have an Imprest Account, unless it is possible to control expenditure from a Central Office, and this latter is what I recommend, and in practice did, whenever possible. The ordinary Army Accounts are sufficient for small works, but when great undertakings have to be carried out, as in Mesopotamia, I am convinced the ordinary Army Accounts are not sufficient; in fact, when in Mesopotamia, I opened a set of books on the double entry system for all the work I carried out there, and had in charge of the books an officer who in private life was a Chartered Accountant. To suit the convenience of the Indian Government Auditor I also had kept the ordinary Indian Army Accounts. The advantages of double entry are that the accounts can be presented to the officer in charge in a compact proved form, and the books can be balanced and records kept in a manner which is admittedly superior to the Army single entry system.

Before making up your mind to build any works to any particular design talk things over with the R.E. Officers of your unit; don't be too shy to go to R.E. Officers outside your unit for advice and help. I was greatly helped in Mesopotamia by Brig.-General Stokes-Roberts, the C.R.E., Works, a very great gentleman, who died out there. If you have in your unit N.C.O.'s who have had practical experience of the type of work you have in mind don't hesitate to take them into your confidence before you tell them what you want them to do. This applies particularly to temporary war-time N.C.O's, as you may easily have in your unit an experienced workman who can set your mind at ease on matters which otherwise may only be known to you from a theoretical point of view or book knowledge.

When ordering supplies in an Allied country don't expect to get them unless you have your own men continually worrying suppliers, and don't pay for any goods until your own men have them in their

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charge. If you have to send or go to an allied or foreign district outside your working area for supplies of materials go to the nearest British Consular Officer and get the assistance of the Consular Staff in any bargain you may make. You may need the Consul's evidence later on to prove that no mistakes in contracts have been made and also for the necessity of any prices you may have to pay. Don't risk laying yourself open to charges of negligence, or even worse, in dealing with Government money. Many officers have had a great deal of unnecessary worry and trouble over both their imprest accounts and contracts they have had to make with suppliers in foreign and allied countries. You may be sure all your expenditure will be scrutinised by people who do not know the why or the wherefore of anything you may have to do. It is most necessary when handling Government money to see first that authority for expenditure is correct, and, secondly, that expenditure can be proved in more ways than one. When dealing with foreign suppliers in either Allied or Foreign ports one must always bear in mind that the custom of the district may be one of *backsheesh* or bribery, and an officer cannot be too careful to keep his name clear of any suspicion of getting mixed up with the customs of the country.

When doing work of the nature above mentioned it will be found necessary to use the labour of the country or Army troops of the country, and it will be found that handling foreign people is somewhat different to handling people in England. My experience is that foreign troops or civilians work better and more satisfactorily when they are supervised by their own officers or nationals than when they are under direct control of English officers. There are exceptions to this, as some English officers got infinitely more work out of foreigners than their own officers, but as a general rule I think the wisest policy is to work through nationals of the party doing the labour. When labourers or Army troops are not being supervised directly by English N.C.O's or officers it is most important that all orders and instructions should be given through the foreign officers or civilian foremen who may be supervising the gang, otherwise misunderstandings and jealousies will flare up. Any complaints an English officer may have concerning the work of foreign labour should be tactfully put forward, otherwise he may find they are taken very seriously, and the men, if Army troops, severely punished, and if civilians a strike may occur. Formal complaints against the work or capacity of foreign army troops are often worse than useless. One must put up with the men one is given and be thankful to get any at all, consequently soft soap and tact have to be used, and more good can be done by talking to an officer over a drink at the camp or a town café than any number of official complaints or rude remarks on the job itself. A sense of humour in handling foreign men is often of more importance than a scientific knowledge of what ought to be done.

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Officers of engineer corps in other armies are usually very scientific and sound engineers. The regular engineers I met in the Italian and Serbian Armies were certainly first-class men used to working with poor material and getting clever work done cheaply. They look upon English methods as wasteful and unnecessarily expensive, they also consider work done by English engineers to be of a too permanent character. When dealing with the foreign engineer officers it is advisable to let them know one is aware of their sound qualifications, and if circumstances suit be guided by their views both on work to be constructed and materials to be used. Accommodation for foreign labour does not have to be on the same scale as for British labour troops, and their feeding is a simple matter compared with the food of British troops. I found there was no difficulty when British N.C.O's had to control Serbian Troops or Italian workmen.

When controlling, temporary R.E. Officers remember they are not in the Army for fun, or because of a career; they most of them want to get the job over as quickly as possible and get back to their own work. They appreciate any kindness or advice a regular may give concerning Army Rules and Regulations, and it is not reasonable to expect temporary officers to know the Rules, Regulations and various Routine and General Orders as intimately as regulars, consequently it is not cricket to attempt to injure temporary officers by catching them on Rules and Regulations. Royal Engineer officers get to be more experienced men of the world during the course of their career, and can see many things from a different angle to that of officers in other branches of the Army. They are respected by other branches and can exercise great influence on the tone of a division or army when on active service.

In war time it is of the greatest importance for engineers to get work done quickly, and consequently peace time practice is not necessarily the best method for war time requirements. In peace time, the cost of work and scientific standards have to be taken into account before and during constructional work, consequently it is often possible to cut down costs and put up better structures by leisurely consideration of plans and delays in construction or placing orders for construction. In war time it may not be practicable to give sufficient time for consideration of plans and estimates. Speed of construction is the greatest factor to be taken into account, risks must and can be taken which, if taken in peace time, would end up in the criminal court, and practically the only point to bear in mind is the utility of the completed work.

In war time it is not wise to depend upon machinery being available for the execution of engineering work, and when planning work which has to be done quickly, it is advisable to consider what classes of plant and labour will be available to carry it out, as these two considerations are of more vital importance to the success of any

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work than all other considerations put together. Much work can be done without machinery, and, when native labour is available, the amount of constructional work which can be done with manual power and ordinary spades, saws, hammers, etc., is astonishing. Heavy weights can be moved, docks dug, wharves built and slipways erected by man power as quickly, or more quickly, than can often be done by machinery when it is available, and if at any time an officer has reason to think there is a possibility of machinery not arriving, my advice is, if man power is available, use the man power and don't depend upon getting the machinery. Ships carrying machinery can be sunk by submarines, and in war time overseas one cannot be sure of receiving any machinery until it is actually landed and erected ready for use.

In handling temporary officers who have engineering qualifications it is as well to bear in mind the fact that the ordinary civilian engineer, when doing his practical work in peace time, has to remember that his living and reputation depend upon work being done properly, consequently he must satisfy himself that the materials and work he is putting into his job are sound and scientifically correct. The result is that in war time, when scientific principles cannot always be followed, and the best materials required are not available, the civil engineer may be apt to prefer delay whilst waiting for proper materials to come along, instead of finishing off the work quickly with bad material, and in consequence it is advisable that the engineer officer responsible for decisions should encourage the temporary officer by taking responsibility from him and advising or instructing him to use the bad material to get the job done, provided, of course, he is of opinion that bad material will last long enough, until better material can be obtained, or if, as is often the case, the temporary work will last until the work is no longer required for military purposes. I remember when building the first wharf at Mahgil, Basrah, the temporary officer responsible for the construction objected strongly to using certain old timber piles which were certainly most unsuitable for constructional purposes, and it was only after he had had it explained to him that either the unsuitable piling had to be used, or the work would be delayed for an indefinite period, he put his heart into the work and made the best job he could. I have no doubt that sooner or later someone responsible for the upkeep of the wharves at Basrah will write a long report damning the military people for using such poor materials in some of the sections of piling. They may even go so far as to say that someone must have made money out of it. The real reason for the use of bad material for this particular work will not be known.

At Taranto, although there is an established port—in fact, two ports, an inner and outer port—the facilities for handling supply ships were very poor, consequently it was necessary to construct

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necessary wharves, and, owing to the difficulty of obtaining supplies from outside Italy, it was necessary to construct wharves, warehouses and camps out of local material as much as possible. Fortunately, underlying the whole of Taranto district is a bed of sandstone, and consequently it was possible to use the stone for constructing the jetties, wharves, warehouses and camps. Skilled Italian workmen were available for stone-cutting, and it was found that to build warehouses and huts of stone was cheaper and quicker than if they were built of timber. The Italians, upon seeing everything being constructed of stone, asked us how long we thought the war was going to last; but many of the British who passed through the camp, not knowing the reason for the great number of stone structures, were rather mystified, as they imagined the buildings of stone in Italy cost what similar buildings would cost in this country. It is a fact that in addition to the many advantages gained by being able to build the principal works of local material, they were actually built more cheaply than if they had had to be built from timber. It must also be remembered that it would not have been possible to obtain timber in Italy. Italy is not a timber-growing country, although in Calabria, near the Taranto district, there are timber forests. The difficulties of getting the timber from Calabria to Taranto were impossible to overcome in war time. The Italian army had to import timber from Switzerland for its own use; in fact, for any timber for housing or warehouse work in Taranto, it would have been necessary to send to England; only rough scaffold poles about 6″ diameter were procurable after much trouble in Italy itself.

One lesson to be learnt from the working of the Cherbourg-Taranto route is that in war time one's Continental allies are so occupied looking after their own interests that it is not reasonable to expect them to be of service to British troops, except in extreme cases.

I think it is agreed that the regular Army forces of Great Britain in the event of a war with a first class or second class power will have to be considered only as the backbone of the land forces required to carry on the war, and that so-called temporary forces will have to be recruited to form the remainder of the body of the Army, and, as history repeats itself, so we may take it that the 1914 to 1918 problems which had to be solved will crop up again whenever any war of importance occurs. The maintenance and success of an army depend to a very great extent upon supplies of expert professional men and materials, and one most important problem which, so far as I know, was overlooked prior to 1914, and may still not be attended to, is that of knowing the positions and records of men who in civil life have the practical knowledge and experience of technical and professional work and of districts, countries or places possessing the

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necessary machinery, craft and appliances. As an illustration of what I mean I can state that I am convinced that if it had been someone's duty in 1914 to keep a list of river steamers and barges in British India and Burmah suitable for use on rivers such as the Tigris in 1914, the Army which attempted to relieve Kut would have had every chance of success, as the whole difficulty of relieving Kut was simply due to lack of means of getting the army up to the front and maintaining it efficiently whilst there. It is not reasonable to expect human beings to do their work on half rations or with the knowledge that medical services have broken down and that guns and ammunition cannot be brought up as required.

Men who join the Royal Engineers have special qualifications, consequently if the best work is to be got out of them they have to be handled somewhat differently to ordinary troops. During the late war many of the temporary R.E. troops received practically no military training. They were to all intents and purposes civilians in uniform and had to some extent to be treated accordingly. I had at times N.C.O's who were Master Mariners, Civil Engineers, Mechanical Engineers, Electrical Engineers, all men who in their particular professions were capable of keeping their own end up in general competition. The opinion of such men had to be taken and considered whenever they were given a job of work to do. The officers of the R.E. recognised this, but officers of other Corps and Regiments very seldom took this factor into account, and when, as in the above mentioned instances of work, I was brought in close touch with officers of Allied Armies, French, Italians and Serbians, I found it practically impossible for these allied officers to realise the work of the R.E. N.C.O's. I found Continental allied officers very touchy concerning their dignity, and they expected to always have to deal with a commissioned officer in the British Army whenever any conversations of any kind had to take place. One difficulty in dealing with allied officers and getting satisfaction when a job of work has to be done is the rule that communications with foreign staffs should be through the staff officers of our own headquarters. This can best be got over by getting the Foreign Staff to attach to the R.E. officer an officer who can deal direct with the Foreign Staff. In small Missions, where only junior officers of the R.E. are attached, the usual thing is for an allied officer to be attached to the English Staff, and as the officer is usually a man chosen more for his tact or knowledge of English, than for knowledge of R.E. work, it simply means additional delay if everything has to go through the Staff, consequently my advice to any one undertaking work in connection with foreign armies is to do your utmost to get attached to your unit a special allied officer, and moreover get him to act unofficially 99 times out of 100.

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If my experiences in the War have any lesson to teach it is that of preparation. I think that if the Royal Engineers are to be responsible in future for the work they were responsible for in the 1914 to 1918 war, then they must add to their present training and gain greater knowledge of the construction and working of ports and rivers transportation. A war in the Far East or Near East would entail a great deal of water traffic. The Navy will always have its own work to do, and I think it has been found in practice that an army must be self-contained.

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THE EARLY YEARS OF THE ORDNANCE SURVEY.

(Continued).

VII.—Thomas Colby.

Thomas Colby.—Mudge was fortunate in his successor. It is difficult to imagine that any officer can have been more entirely fitted to direct the survey of this country than Thomas Colby. He had joined the department as a young subaltern in January, 1802; he became Mudge's right-hand man and took a large share in the general conduct of the operations during Mudge's life-time; and on Mudge's death, in 1820, he was appointed by the Duke of Wellington to succeed him: but not until the Duke had thoroughly satisfied himself that Colby was the right man.

Mudge died on the 17th April, 1820, but Colby was not appointed until the 10th July, by a letter from the Office of Ordnance of that date, signed by Lord Fitz-Roy Somerset:—

"I am directed by the Master-General to acquaint you that His Grace appoints you to succeed the late M.-General Mudge in the superintendence of the Ordnance Trigonometrical Survey; and the requisite notifications have been made accordingly."

During the three months' delay, Colby, not unnaturally, became a little restive, and wrote to His Grace on the 20th June a somewhat lengthy letter, in which the following passages occur:—

"I have used no interest, I have solicited no one of your Grace's noble friends to paint my character or conduct on the Survey in glowing colors; but I have had a firm but humble reliance that your Grace would, when the press of more important business allowed opportunity, enquire how far my conduct and character would render me deserving of confidence and enable me to conduct the Survey with efficiency and credit to the country."

He then mentions, as men qualified to give an opinion on his work, "Dr. Charles Hutton, of Bedford Row, the late very eminent Professor of Mathematics at the Royal Military Academy; Professor Bonnycastle and Dr. Gregory, of the Woolwich Academy; Dr. William Pearson, of East Sheen; the Professors of Natural Philosophy and Mathematics at Edinburgh, Aberdeen and St. Andrews."

This letter produced an immediate answer, which, judging from its style, was perhaps dictated by the Duke himself:—

Office of Ordnance,
21st June, 1820.

"Sir,

"I am directed by the Master General to acknowledge the receipt of your letter of the 20th instant, and to acquaint you that His Grace is

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now making enquiries, and will let you know whether he will appoint you permanently to conduct the Survey or not. In the meantime, the Master General begs you will continue it, in like manner as General Mudge would have done.

" His Grace at the same time desires me to inform you that he entirely approves of your not having urged any of your Friends to apply to Him; and that you may rely upon it that neither upon this, nor upon any other occasion, could a private application be made to the Duke, without diminishing the favourable opinion which His Grace might entertain of the person in whose behalf it should be made.

" I am, etc.,

FITZ ROY SOMERSET."

His Grace proceeded to consult various scientific men as to Colby's fitness to take charge of the Survey, and amongst others he wrote to Sir Humphrey Davy, who replied that not only was Colby the officer best fitted for the appointment, but that it was in a sense his right, as he had been so long in charge of the greater part of the work. The Duke also sent for Dr. Hutton, and the story of the interview is told in several ways. The doctor, on entering the room, was at once asked by His Grace if Colby was the best man to take charge, and began a speech, " No man more so, My Lord Duke . . . " when the Duke cut him short with, " Thank you, Dr. Hutton, that is all I want to know; my time is valuable, and yours, I know, is not less so." And so Colby was appointed.

He was then a captain, and the Board of Ordnance paid him, on appointment, £1 7s. 8½d. a day, or about £500 a year.

He remained Director of the Survey until his retirement from the Army in 1846. He was, thus, continuously employed in the Department for 44 years, and during 26 of these he was in control of it. Like Mudge, he was devoted to his subject. Like him, also, he had many official difficulties to contend with, and had to put up with the same indignity of an official enquiry into his work. But, before he retired, he had the satisfaction of seeing the Ordnance Survey firmly established in public and official estimation, and he had succeeded in greatly expanding the scope of its activities and in increasing its usefulness to the country.

According to Portlock, whose *Memoir of Major-General Colby* is the principal source of information with regard to Colby's early life,

" The grandfather of General Colby was Mr. Colby, of Rhosy Gilwin, Newcastle Emylin, South Wales, a gentleman of considerable landed property. His father, Thomas Colby, was an only son, and an officer of Royal Marines. For many years he appears to have been attached to the Chatham Division of Marines, and at that station most, if not all, of his children were born, the births of four being recorded in the registry of St. Margaret's *next* Rochester."

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Captain Colby was severely wounded "at the glorious battle of the 1st of June," 1794.

Colby's mother was Cordelia, sister to General Hadden, R.A., a distinguished soldier. Thomas Frederick Colby, the future Director of the Survey, was born on the 1st September, 1784, at Rochester, and his early years were passed either at Rochester or Chatham; but, when his father again went to sea, he was put under the care of his father's sisters at the family seat, Rhosy Gilwin, and by them brought up until sent to school at Northfleet in Kent. From Northfleet he went to the R.M. Academy, Woolwich, and was commissioned as second-lieutenant of Engineers on the 21st December, 1801.

In the following January he was posted to the Survey under Mudge, whose letter to the Master-General reads:—"I find him, on examination, well grounded in the rudiments of mathematics, and in other respects perfectly calculated to be employed in this business. I beg to point out to your lordship the expediency of Lieutenant Colby being attached to me with some degree of permanency, and to request you will assign him to my orders on that principle." He was posted to the Survey on the 12th January. There cannot be any doubt that General Hadden, then Surveyor-General of the Ordnance, was the prime mover in his nephew's appointment, but it is equally certain that Mudge was satisfied that young Colby was fitted for the work. In after years he had every reason to be pleased that the Surveyor-General's nephew had been chosen. As to the "degree of permanency," we have seen that Colby remained "in this business" for 44 years.

Although Colby was christened *Thomas Frederick*, he never seems to have used the second name, but always signed himself T. Colby or Thomas Colby.

In 1803 Colby suffered an accident which materially affected him for the rest of his life. He was engaged on a tour of inspection, and was examining Mr. Dawson's work on the interior survey of Cornwall, and that of his first batch of pupils, when the accident occurred.

Mudge thus describes it in a letter to General Morse, dated Liskeard, December 16th, 1803:—

"I am extremely sorry to announce, for your information, a most unfortunate occurrence. On Monday last Lieut. Colby, in the act of placing an overloaded pistol on the ground, was severely wounded from its going off unexpectedly: his left hand grasped the barrel and was so violently injured that amputation became necessary: it accordingly was taken off just above the wrist the same evening. The loss of his hand is not the only misfortune to be deplored, as his skull received a violent blow, producing a fracture in the forehead. . . . The brain, it seems, remains free from any injury; nor is any future evil apprehended, beyond a scar.

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" Mr. Dawson, with whom Lt. Colby was living, and to whose house he was brought, took every proper step, and amongst others immediately sent to me. I consequently came with all possible speed. It is . . with a degree of satisfaction proportionate to my regard for this most excellent but unfortunate young man that I have to state the confident expectations entertained of his recovery, without the smallest injury to his intellects."

Colby was a man of unusual strength of constitution, and he recovered; but for the rest of his life his forehead bore the mark of the accident. He accustomed himself to observe with the large instruments, though he had only his right hand. Portlock, who knew him well, wrote in the *Memoir* that it was " impossible not to recognise in the injury inflicted on his skull a sufficient cause both for subsequent bodily ailments and for a reluctance to enter on long continued mental exertion." However that may be, there is abundant evidence that the injury did not, in later years, materially affect his activity either of mind or body, though we may, perhaps, attribute to it a certain unwillingness to tire himself with controversy.

It has been seen how much personal work Colby carried out during Mudge's directorate. The following letter from Colby to Mudge describes some of the conditions of work in Scotland :—

Benclach, near Alton,
24th July, 1818.

" The country which we have now to deal with is so extremely wild and destitute of accommodations of every kind, and the mountains are so high and difficult of access, and, moreover, seem at such long distances, that they require larger objects than those that were wont formerly to be erected, in consequence I have been compelled to send two men together instead of one alone to erect the objects, and the allowance of 2s. 6d. each object heretofore granted is become obviously too small. I have, therefore, to request that you will sanction me in raising it to 3s. 6d. each object. . . In this, as in everything else which regards the Survey, I have paid the utmost attention to economy, and I am willing to try the effect of what I consider as a minimum allowance. . . In the western part of Scotland, from the want of roads and carts, and the extreme height of the mountains, no station can be visited without very considerable expense, and I shall, therefore, endeavour to perform the Survey of it with as few stations as possible by the intersections of objects on the mountains, which will serve all the requisites of the map. . . "

Portlock includes in his *Memoir* an account, written in 1852, by Major R. K. Dawson, of a season spent under Colby's command in the Highlands. This account, from which the following paragraphs are extracted, gives an excellent picture of Colby's manner of life when at work, before he became Director of the Survey :—

" In the month of May, 1819, Lieutenant Robe and myself were appointed assistants to Capt. Colby on the Trigonometrical Survey,

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and on the 5th June following I embarked in charge of a selected party of artillerymen, the instruments, and camp-equippage, for Aberdeen. . .

" We were joined at Huntley by Captain Colby, he having travelled through from London on the mail coach. . . . This was Captain Colby's usual mode of travelling, neither rain nor snow, nor any degree of severity in the weather, would induce him to take an inside seat or to tie a shawl round his throat; but, muffled in a thick box-coat, and with his servant Frazer, an old artilleryman, by his side, he would pursue his journey for days and nights together, with but little refreshment, and that of the plainest kind—commonly only meat and bread, with tea or a glass of beer.

From Huntley, Captain Colby proceeded with us on foot, and on the second afternoon we reached the base of the mountain [Corrie Habbie] in Glen-Fiddick, near to a hunting lodge of the Duke of Gordon. Here, by partially reducing the loads on the cars, and by the application of guy-ropes to support them, and with the men's shoulders to the wheels, we climbed up as far as we could; and, having unloaded the cars, made an irregular kind of encampment for the night. It was a fine evening; and we had need, therefore, of but slight covering; and anything like luxury was, of course, out of the question. A marquee was pitched for Captain Colby, in which he slept, in his clothes, on a bundle of tent-linings; and I, knowing no better, was content to put up with the like accommodation; but Robe, who had recently been with the Army of Occupation in France, like an experienced campaigner, set to work with his Portuguese servant, Antonio, who had also been with him on the continent, and soon put up his camp bedstead, and made himself much more comfortable—a lesson which I did not fail to profit by in my after-experience.

" On the following morning the really laborious part of the business commenced, that of conveying the camp-equippage, instruments, and stores to the top of the mountain. Horses were hired for the purpose and made to carry the packages slung like panniers over their backs, so far as the ground proved tolerably even and firm; but when it became broken and hummocky, which is commonly the case with peaty soils, or springy and wet, there was then no alternative but to unload the horses and carry the things on the men's shoulders. . . Captain Colby went on, taking Robe and myself with him, to the summit, where he selected a spot of ground for the encampment as near as practicable to the station, and also for the watch-tent, at a point much nearer still. He then selected a suitable place for a turf-hovel, to be built on the sloping face of the hill, with a tarpaulin roof, in which to make a fire for cooking, and for drying the men's shoes and clothes, and to serve also as a place of shelter and warmth for the men in tempestuous and severe weather. When some of the tents had been brought up, and one or two of them pitched for present use, a party of the men were withdrawn from this duty, and employed in pulling down the conical pile of stones built round the station-staff, and in setting up in its place the observatory-tent. The requisite steps were then taken for securing the table or stand, for the great theodolite; and the theodolite itself was then brought up with special care and fixed in its position. . . .

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"When the arrangements in the observatory had been completed, and the summit of the hill was free from clouds, every moment favourable for observation was anxiously caught by Captain Colby, and devoted to that service, from sunrise to sunset. At other times he imparted to Robe and myself a knowledge of Ramsden's great three-foot theodolite, and of its adjustments, as also of the mode of working and entering the computations. . .

"29th of June.—Captain Colby took Robe and a small party of the men on a 'station hunt,' or pedestrian excursion, to explore the country, along the eastern coast of Invernesshire, Rosshire, and Caithness, and to erect objects upon some of the principal mountains, and select those which from their position and circumstances should be preferred for future encampments. . .

"21st of July.—Captain Colby and Robe returned to camp, having explored all the country along the eastern side of the counties of Inverness, Ross, and Caithness, as well as the mainland of Orkney, and having walked 513 miles in twenty-two days.

"23rd of July.—Captain Colby took me and a fresh party of soldiers on a station-hunt, to explore the country to the westward and northward of west."

The first day they walked 39 miles, having "crossed several beautiful glens" and avoided the beaten track as much as possible. In the middle of the second day Dawson thought that he really could not stand any more of it, and "petitioned strongly" to be excused from accompanying Colby. But the latter would not listen to his subaltern's petition and Dawson had to limp along. But he soon got broken in, and in a day or two was able to walk with the best of them. They got back to the top of Corrie Habbie on the 14th August, having walked 586 miles in twenty-two days.

Dawson (junior) says that on Sunday, 1st August, 1819,

"I so far forgot the sacred nature of the day as to commence whistling some light air. Captain Colby very properly checked me in so doing, explaining to me the deep sense of veneration with which the people of that country regard the Sabbath, and the next day I was informed, while on the march, by one of our men, that he had been urged by the landlord to come to me and beg me to cease whistling, dreading that some judgment should otherwise fall upon his house."

The Duke of Gordon helped in every possible way whilst the party was in the neighbourhood of Glen Fiddick, and came up the hill frequently to see Colby. He took no small interest in the work and carried out some of the barometer observations himself. The observations with the great theodolite were finished on the 28th September. After the instruments had been safely packed, Colby gave the men *carte blanche* to provide themselves a farewell feast.

"The chief dish on such occasions was an enormous plum-pudding, the approved proportions of the ingredients being—a pound of raisins, a pound of currants, a pound of suet, etc., to each pound of flour; these quantities were all multiplied by the number of mouths in camp, and the

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result was a pudding of nearly a hundred pounds weight." This gigantic pudding was suspended by a cord from a cross-beam and boiled for twenty-four hours in a brewing-copper. "A long table was spread in three of the marquees, pitched close side by side and looped up for the purpose, and seats being placed also for Colby and his subs., we partook of the pudding, which was excellent, and withdrew, after drinking '*Success to the Trig.*'"

R. K. Dawson says that, after Colby was appointed Director, he was out with Vetch, Drummond and himself, in 1821, in the Orkneys and Shetlands, and in the solitary islands of Faira and Foula. In 1822 Colby was with Vetch and Dawson exploring the whole range of the western islands of Scotland. In 1825, the scene having shifted to Ireland, he camped on Divis, and in 1826 on Slieve Donard; and was not again in camp for any length of time until the resumption of the Survey of Scotland in 1838.

As the result of the report of a Select Committee of the House of Commons, the Survey of Ireland on the scale of six inches to one mile was commenced, under Colby's direction, in 1825. But the Tower of London still remained the Survey headquarters, although all but one of the officers were transferred to Ireland; Richard Mudge only, with a few engravers (and perhaps one or two of the surveyors engaged on the English detail work) remaining at the Tower. Colby himself led a migratory existence, being sometimes in Ireland and sometimes in London. The triangulation of Scotland was stopped, and no further work was done on it until 1838.

The last winter that all the officers were present at the Tower was that of 1824-25. Portlock says that Colby's "ardent zeal and craving for improvement spread quickly amongst the young officers serving under him, and setting them also thinking and working," rendered the winter memorable in the annals of the Survey. The officers were:—Richard Mudge, Robe, Drummond, Murphy, Dawson, Lacom and Portlock. Drummond's quarters in Furnival's Inn "became a laboratory and workshop." Everyone who knew Colby in those days "must remember how rapidly he moved or ran through the streets, rarely relapsing into a simple walk; and it was thus that I met him rapidly descending Tower Hill, when he took my arm, and with the usual, "Come, my boy, I have something to talk to you about," carried me back with him to the map office in the Tower, which was not only the office for the business of the Survey, including the engraving of the maps, but also contained the private apartments allotted to Major Colby as director of the work."* Portlock had dinner there with Colby, who explained to him his idea of compensation bars for base measurement, it being certain that a base would shortly have to be measured in Ireland.

* Portlock's *Memoir of General Colby.*

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In 1828 Colby married Elizabeth, the second daughter of Archibald Boyd, of Londonderry, and took a house in Mountjoy Square, Dublin. In 1830 he rented Knockmaroon Lodge, close to one of the gates of Phœnix Park, and a few minutes' walk from Mountjoy House, which had become the headquarters of the Survey of Ireland. He had four sons and three daughters. Two of the daughters, Anne and Cordelia, survived until within a few months of the writing of this paragraph; they died at Clifton in the autumn of 1924, within a few weeks of each other, having lived to a great age, and to the last were keenly interested in the memories of their father's life. They entrusted to the present writer a great number of letters and documents which had been collected by their father.

In the collection above mentioned is a bundle of (copies of) letters written by Colby to his wife, between 1830 and 1844, covering a great part of the period of Colby's administration of the Survey of Ireland. In a letter written on the 8th May, 1830, from Liverpool to Knockmaroon Lodge, Colby says :—

" We went in a fly to the railroad and walked about a mile, where stupendous excavations through rock are in progress. We then got upon the steam carriage and went a mile with a dozen wagons fastened to our rear. The perfect ease with which these carriages can be managed is really beautiful—not like the pulling and hauling with horses. We could run up to a thing, and push it along in the most gentle manner without the slightest concussion, and stop or go backwards or forwards with equal ease. As the steam had got low and no experiments were in progress, we only went at the rate of 16 miles an hour."

On the 28th May :—

" On my arrival [in London] I found things in somewhat of a new train and that my influence in society was not in the least improved by my having been bottled up in Ireland for the greater part of a year. The Civil Engineers Club has almost ceased to exist. The Astronomical Society have got a little bad feeling among them. The Royal Society have a similar evil to contend with. The Athenæum are not in the most thriving possible state, and the Geological alone remains uninjured by folly or party feeling. . . A new Geographical Society is started and I am one of the provisional committee for its management. It bids fair to do well. Lord Aberdeen and all the leading people in his department, Lord Melville and the principal Naval characters, and, indeed, most of the Ministers, are in it. . . I have paid £5 to the Charter fund of the Astronomical Society; £3 12s. to the Geological Club, and £2 8s. to the Royal Society Club; £1 for silk stockings and 16s. 6d. for shoes—you see I am not extravagant."

June 3rd, 1830, Tower to Knockmaroon :—

" . . . I dine with Lord Hill, the Commander of the Forces, on the Saturday after next, and I have a Member of the House of Commons on the look-out to assist me in getting at those I want to aid in carrying my public objects in relation to the Irish Survey. I mean to be a little

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more independent of the good or bad will of the Master General when I return; at least things are getting into train. The Member I allude to is not in office, but he is a personal friend of the Duke of W., Lord F. Somerset, Sir H. Hardinge, and of Peel and the other leaders of the Ministerial party. I am also at work through another channel to secure the support of Lord Lansdowne and that party. I am not asking personal favours, and therefore no interested motive can appear to operate against me. I have also taken further steps to secure the Survey against any unpleasant observations from Mr. Hume and his party; and I have also a promise of a committee next session for the Survey if I want support. You see, I have been on the look-out here."

23rd June, 1830:—

" . . . I have been working away for Ireland at a great rate, to get the bogs drained, etc., but the difficulties are enormous. I was yesterday first with Lord Downes (who, by the way, is turned civil and asked me to lunch at his house) and Colonel Rochfort about it. Next I went to the Irish Office to push the matter with Sir Charles Flint and the Irish Government, then to Sir Thomas Towlins, who is drawing the Bill for the drainage, and then to the House to get Brownlow and Sir H. Parnell rather to let the Bill pass with clauses which may impede its working than to throw it out altogether. It is uphill work and I would rather be at home, but I believe that I have saved the Bill from being thrown out. . "

December 2nd, 1831, London to Knockmaroon:—

" . . . You would have been amused if you had heard the *odd* speeches at the Royal Society Dinner. The Duke of Sussex evinced much good humour. When he gave the Queen's health, he told us that 'she contributed to the King's comfort,' and he called the Royal Society the 'Mamma' of the new societies, and he designated himself the Husband of the old Mamma.' He told us it was difficult to find men who would tell princes the truth, and that he could only get at it now and then by stealth. He drank wine with a few individually at dinner, and with the remainder in parties of six or seven. There were few great men there, and I was included among those who received the individual compliment. . ."

February 14th, 1832:—

" . . . Our new clerk, Mr. Kennedy, seems a sensible, straightforward, intelligent man. He is to be with me at the Tower on Thursday."

February 28th, 1832:—

" . . . When I am no more, I trust those I leave will not think it necessary to pay any pompous respect to the worthless remnant of what once was me. The tribute of sincere affection is all I desire, and the cheerful belief that my conduct below has not rendered my removal a matter to be regretted on my own account. But while I am here, it is my duty to do the best I can for those I love. I, therefore, take as much care as I can to prolong my existence."

December 4th, 1832, Tower to Knockmaroon:—

" . . . I dine to-day with Sir James South and on Thursday with

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the Master General. But my official duty is very uphill work, though we are all personally on the most friendly terms."

May 9th, 1833 :—

" I have had a long private audience with the King to-day. He was very gracious, and looked over the whole atlas of Derry very carefully, sheet by sheet, asking questions about them and the Survey, and expressing his approbation, not only of the maps, but also of his Corps of Engineers and Artillery and of the Ordnance Department under which the work was executed. When Sir James Kempt introduced me, the King said,' he ought to have been ashamed of himself for not immediately remembering Colonel Colby '— that he thought I had belonged to the Artillery, and did not recognise me in the Engineers' uniform.

" It is gratifying that the first Irish map has been so well received."

In January, 1834, Colby suggested to the authorities that Captain Richard Mudge should carry on the English Survey independently, in order that he, Colby, might devote his whole attention to the completion of the Irish work. This is a proof that the English survey was still being slowly proceeded with, although the survey of Scotland had been stopped. It appears that the authorities still left Colby in general charge of the English work. " I had made up my mind to the sacrifice of my salary for the sake of advancing the Irish work." In later years he did undoubtedly sacrifice a large part of his salary for the same object, but it does not appear that this happened in 1834.

In September, 1835, he says that he has been down to Woolwich with Sir H. Vivian to see " the new Pontoon Bridge of Major Blanchard's invention. . . I returned with Sir H. to London . . . went straight to the Tower, did my business, and dined with Robe close to the Tower."

May 29th, 1837 :—

" Babbage has published a new book on Natural Theology, and his parties are crowded to excess. He gives one every Saturday, and as I came home past his door last Saturday, I am sure there were more than a hundred carriages waiting."

May 26th, 1837 :—

" . . . My having been in London is most fortunate, for poor Dawson's complete failure in the tithe commutation business would have cast a sad damp upon all our work if I had not been here to avert the evil. The Scotch are coming forward for their Survey in good earnest. The Societies have petitioned, and some influential men see the Chancellor of the Exchequer to-morrow about it. A more powerful mass of noblemen and gentlemen are coming forward on that point, and it is quite necessary that I should be here to guide and prevent such blunders as have happened in the tithe commutation business. There is nobody that I could trust to put in charge of the Scotch Survey, and I suppose I must make it part of my business. All the leading movers of the matter are my personal friends."

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May 7th, 1838 :—

" . . . Left the Tower about ½ past 3 o'clock, and went to the Engineers' Office. All gone but Colonel Wells. Went into the Ordnance Office, had a long conversation with the Master General ; asked to dinner on Sunday. Went to the Club. Murchison kept me a good while talking about geology."

May 19th, 1838 :—

" . . . I breakfasted to-day with a party at Mr. Baily's, lilies, tulips, etc., in the middle of the table—broiled salmon, roast pigeons, cold fowl, ham, plovers' eggs, prawns, and a party of philosophers : Sir John Herschel, who has just returned from the Cape of Good Hope, the Editor of the Nautical Almanac, Captain Smyth, the Professor of Natural Philosophy from Edinburgh, two Cambridge professors, Baily and I. Sir John enquired after you. . ."

June 5th, 1838 :—

". . . Jervis and Lock, the Director of the E.I. Company, took my time yesterday at the Tower."

June 6th, 1838 :—

" . . . I dine at Mr. Baily's to meet some of the foreign astronomers. These dinners are sad hindrances. We had a very good dinner at the Greenwich Observatory Visitation on Saturday and a very pleasant party of about 16—Mr. Baily in the chair—the astronomers of Greenwich, Cambridge and Edinburgh, Oxford, etc. Healths drunk, speeches, etc. Colonel Pasley has succeeded in blowing up two wrecks, and he is quite happy."

July 9th, 1838 :—

" . . . On Saturday the Duke of Wellington came to the Tower to present the new colours to the 20th Regiment, and after the presentation he did me the favour to call at the office, with Lord Hill, Lord Fitz-Roy Somerset and several other general officers, and I had the honour of shaking hands once more with my old and much esteemed Commander."

Writing from Perth, where he had gone to make arrangements for the resumption of the Survey of Scotland, Colby says :—

" Sir Charles Gordon told me that if I wished to have introductions to any of the proprietors, that the members of the Highland Society would be happy to give them to me, and they have put a paragraph in their report, expressing their wish that every assistance shall be given to the persons employed on the Survey throughout Scotland."

December 5th, 1838 :—

" . . . Jervis is working away to get my system introduced in the Indian Survey ; but as yet he is violently opposed by all the East India underlings."

May 8th, 1840 :—

" . . . I had a very long conversation with Sir Hussey yesterday morning about the proposed survey of Scotland. . . I have had heavy work to face all opposition, but the Engineer Office are now very civil to me—and everything is apparently smooth. The Inspector General has recommended the instruction of the young officers of Corps, and

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non-commissioned officers on the Survey. This is complimentary, but what will Pasley say to it? . . . We are friends now, and both Ellicombe and Fanshawe are on my side. When I was buried in Ireland I had no opportunity for meeting difficulties."

In 1842 the headquarter offices of the Survey were established in Southampton, and Colby's letters from this date are mostly written from that town or from London. On October 31st, 1842, he says that he has seen Lord FitzRoy Somerset and Sir Henry Hardinge about the new scale of the English survey. On November 4th he writes that he left Southampton at 11 and got to London at 2.

On the 5th November :—

"The Engineer Office and the Ordnance Office were very civil to me to-day—perhaps they think it as well to be so as the Master General does not agree with them against me."

November 10th, 1842 :—

"Not many years since the value of a knowledge of Latin and Greek with a good flow of language for public speaking were so great that a man possessing them was allowed a high station in society, and supposed fit to govern others; though he might have been profoundly ignorant of everything but *words*. These times are changing. Men who learn to think aright, and to know what is going on both in the natural and moral world are rising in importance. The conceit which is engendered by ornamental or unsubstantial knowledge is giving way."

November 17th, 1842 :—

"My base apparatus has returned from the Cape of Good Hope, and I am in daily expectation of its coming here."

November 28th :—

"Yesterday was a fine morning and I walked to Romsey, where I heard a good sermon in the church there."

December 4th :—

"I am still in the dark as to what is to be done with the Survey, though I have just had a long conversation with Sir George Murray, the Master General, who is well disposed to me about it."

From an undated letter :—

"The little strip inside are penny postage stamps; by wetting one of these and sticking on the back of a letter not weighing more than half an ounce, you save sending a penny to the post office."

February 11th, 1843 :—

"I stand alone, with all the Surveyors in the kingdom against me—with the desire of the Inspector General's office (under whom I act) to take every opportunity of opposing me—with the Board of Ordnance mostly against me—the Master General neuter, and the Treasury desirous of putting the money spent under my direction under some one who will be less honestly inclined to prevent their exercise of patronage in appointments; and, my only chance of standing alone against this opposition, is that everything done under my direction shall be quite unimpeachable in every respect, for I have neither money to bribe

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by good dinners, or health or leisure for political intrigues. . . During the last 12 months I have refused 65 applications for employment—many of them recommendations by noblemen, and influential members of the House of Commons; and several by the Master General and Members of the Board of Ordnance." . . .

November 12th, 1843:—

"My department is so powerful that I can (if they will allow money enough) carry on the American boundary, the Hong Kong Survey, the London Survey and the Scotch Survey, without checking the English or Irish Surveys."

December 12th:—

"Yesterday evening I went to the Geographical Society, where they had more of Dr. Beake's account of Abyssinia. But certainly we knew no more about its geography when we left the room than we did when we came into it."

10th February, 1844:—

"I had a very complimentary note from the Foreign Office last night, about Captains Robinson and Pipon and my sappers that I sent from the Survey to settle the American Boundary."

And on February 21st:—

"I have just been reading two very amusing and cheerful letters from my officers, Captains Robinson and Pipon, who are at work with some of my soldiers on the American Boundary. They cannot tell the degree of cold because the mercury is in the bulbs of all the thermometers. It is, therefore, more than 32 degrees below freezing; and they are obliged to keep all the chronometers in a room with a fire, and a sapper to repeat the *ticks* loud for them to hear in the observatory, because it is too cold in the observatory for the chronometers to go."

Colby was a man of religious temperament and took a lively interest in church affairs. He deplored the state of things that then existed in Wales. Being also a man of science, he had no patience with those ecclesiastics who ignored, decried, or derided the conclusions of organised knowledge; and it may be remembered that in his day the new teachings of geological discovery were beginning to be appreciated by the public. On February 27th, 1844, he writes:—

"I met a gentleman who has property at Cheltenham yesterday evening. He was giving me an account of the ignorant bigotry of Close, and his violent attacks on science."

On March 25th:—

"Wales will be improved *in spite* of the Welsh [Colby was himself Welsh].

Again, with regard to the church in Wales:—

"I feel convinced that the whole government of the Established Church requires a change, and regret that the clergy are the last to see the necessity for a reform."

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Whilst the Survey of Ireland was in full swing, Colby's permanent house was Knockmaroon Lodge, although he was, for long intervals, in London, looking after the interests of the work. In 1838, when the survey of Scotland was resumed, Colby left Ireland and lived in London. In October, 1841, the Survey offices in the Tower of London were burnt down, and in 1842 the headquarter offices were removed to Southampton. From this year until his retirement in 1846 Colby lived principally at Southampton. Colby's retirement took place at the moment when the last of the Ordnance maps of Ireland on the six-inch scale had just been completed and published.

It appears from a letter written by Sir John Burgoyne that Colby voluntarily retired, after being promoted to the rank of Major-General. It was not the case that he left the Survey on account of his promotion, but rather that he thought it time to take a rest from the prolonged labours of forty-four years. After leaving the Survey he took his family to Germany and Belgium, in order to educate his sons. He was not well off, but had taken the unusual step of relinquishing his salary for the last five years of his active employment. It is said that :—

" Colby did not hesitate, year after year, to take upon himself the responsibility of exceeding by large sums the rates sanctioned by Parliament, rather than diminish the rate of expenditure and progress by discharging qualified assistants. To keep down current expenditure, Colby for some time did not draw his own salary. When he subsequently applied for arrears they were refused and never paid."*

This statement is borne out by a letter from Richard Mudge of the 20th July, 1848 :—

" MY DEAR SIR,

" If anything has given me more surprise than for a very long time, it is the fact you mention, and which I learned for the first time from your letter that the Board of Ordnance had withheld your salary for the Survey of Ireland for the last five years preceding your quitting the Survey. It is so unjust and absurd that I am sure it must eventually be paid, although it may require the interference of some person of weight and influence with the present Government to obtain it. I think that your claims are of a much greater amount. . . The Survey of Ireland is one of the most important and successful undertakings of late years and was conducted throughout and to what may be termed a conclusion by a continuation of firmness and perseverance which I assure you always impressed me with pleasure and admiration. I knew a great deal of what you had to contend with and of some of the difficulties and impediments that were thrown in your way." . .

However, he never got the whole of his money back, though it appears that he was repaid a small fraction of it.

* *Dictionary of National Biography. Article, Thomas Colby.*

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One of the many advantages of Colby's long residence in London was that he became very intimately connected with the various scientific societies which have their headquarters in the metropolis. He was a Fellow of the Royal Society. He was an original member of the Royal Astronomical Society, and helped to draw up its rules. He assisted at the formation of the Royal Geographical Society, and was a Fellow of the Geological Society. He was an Honorary Member of the Institution of Civil Engineers and frequently attended the meetings of that body. He was given the honorary degree of LL.D. by the University of Aberdeen. But, except for promotion to Major-General, he never received any recognition from the various governments that he had served.

Colby had a wide circle of friends and correspondents. Amongst soldiers, Hardinge, Fitz-Roy Somerset (afterwards Lord Raglan), and Burgoyne, Pasley and Everest; amongst sailors, Raper, Hurd and Beaufort; amongst men of science, Banks, Faraday, Airy, Kater, Brewster, Murchison, Herschel, Baily, Hutton, Sheepshanks, Sir W. Hamilton, Sedgwick, De la Beche, Peter Barlow and Gregory; and in the larger world, Rowland Hill, Robert Stevenson, the engineer, Lord Macaulay, and Sir Thomas Brisbane. He was clearly happiest in the atmosphere of learning, and never more at home than when in the company of his friends of the learned societies, at the various dining clubs to which he belonged, or when taking part in the proceedings of these societies.

The unsettled state of affairs on the Continent induced him to return to England with his family in 1848, and a few years later "with little or scarcely any warning, the spirit, yet active, was summoned from the body, yet firm and hale, and on the 2nd October, 1852, in the 69th year of his age, whilst amid his loving and mourning family, at New Brighton, near Liverpool, he passed from the scene of so much bodily and mental exertion to rest and peace eternal." * Portlock goes on to say that he learnt to appreciate Colby's "accurate knowledge, his sound judgment, his untiring energy and consummate skill, and, above all, his unbounded liberality in imparting to me and others the stores of his own knowledge."

One more tribute to Colby's memory may be given: that written by Sir George Airy, the Astronomer Royal. Airy and Colby were friends and had been in close touch for a great number of years. Colby knew how to value Airy's great gifts, and Airy was ever ready to help the Survey. There is no trace of the hard and unpleasant side of Airy's character in his relations with Colby or the Ordnance Survey. Airy writes in 1869 to Mrs. Colby:—

"We both were members of the Board of Longitude, which was dissolved in 1829 (I think). . . At one of my Irish visits I had the happiness

* Portlock's *Memoir of General Colby*.

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of enjoying the hospitality of Knockmaroon Lodge; and in later years, when Colonel Colby was for a long time fixed in London, I and my family had the gratification of receiving him very often at our Sunday dinner at Greenwich. We can all bear testimony to his kind and social disposition; his appearance was always a source of friendly pleasure to us. I was often struck with the peculiar adaptation of Colonel Colby's talents and habits to the great work which he directed and the great system which he principally created. With the scientific geodetic problem before him he was familiar. On the grand points of execution, such as the large scale triangulation (I may well use that epithet for a triangulation which described the length of Ireland in three steps and its breadth in two), he was clear in his own judgment and decided in his provisions for carrying them out. . . The order of his offices was admirable. His attention to the accuracy of instruments of every kind was very great. And all this devotion of himself to his great work appeared to be wholly unselfish. I never heard a word from him which implied that he was looking abroad for personal glory, or for any expression except the recognition of his results as producing a scientific survey superior to any that had ever been made, and a cadastral mapping to which no other, I believe, can be compared."

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MAJOR-GENERAL THOMAS COLBY,

R.E., LL.D., F.R.S., &c.

1784—1852.

Director of the Ordnance Survey,

1820—1846.

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MODERN HEAVY OIL ENGINES.

By CAPTAIN R. M. H. LEWIS, M.C. R.E.

In view of the probable adoption of the "airless injection cold starting heavy oil engine" ("loosely termed" the cold starter) for army purposes in place of the old Hornsby type of slow speed horizontal paraffin engine, this article has been written (*a*) to attempt to make clear the differences between the semi-diesel, the diesel using air blast injection and the cold starter; (*b*) to compare briefly their relative merits; and (*c*) deal with the main points in cold starter design.

Although official definitions for the semi-diesel and diesel engines have been got out by the Diesel Engine Users Association, no definition of a "cold starter" has yet been devised: mainly because the cold starter, although now an economic proposition, is only just emerging from the experimental stage. The various attempts at getting a true cold starter were too diverse for a definition to be devised which would cover them all and yet exclude the semi-diesel and the air blast diesel.

Cold Starter design, however, has now settled down into two main channels: (*a*) The marine type, not found in small sizes, which has been evolved from the air blast injection diesel (hereafter called the diesel for short); (*b*) The land type, found in sizes from 10 h.p. up to 950 h.p., which has been mainly evolved from the semi-diesel.

While the general design and principles of the diesel and semi-diesel can be found in any text book, it is necessary to summarise briefly here their relative advantages and disadvantages for comparison purposes with the cold starter, about which last, so far as the writer is aware, there is no extensive literature available except the makers' catalogues.

The semi-diesel engine is an engine working on the constant volume cycle designed to use the lighter types of residual oil.

To make ignition possible the oil has to be split up or atomized into a fine spray. This is done by means of a fuel pump which forces the oil, under varying pressures, up to 1500 lbs. per square inch, through one or more fine holes in what is known as the pulverizer, into the engine vaporizer.

The resultant mist of fuel is then ignited by means of the heat of compression *aided by the heat of an uncooled portion* of the cylinder head.

Herein lies the root of semi-diesel troubles.

(*a*) External heat has to be applied to the engine to start it, i.e., it is not "cold starting." In the past this heat has usually been

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supplied by heating up the uncooled portion of the head with a blow-lamp. This operation takes up to twenty minutes to do, and a blow-lamp is a messy affair and increases the fire risks.

This difficulty has been largely got over by the use of quick starting devices, e.g., heating up a coil of wire electrically or burning a patent cartridge in the cylinder head. These devices supply the necessary heat for starting and enable the engine to get away in about two minutes. They, however, usually entail auxiliaries such as a battery or a supply of cartridges.

Some semi-diesel makers are doing jackal to the cold starter lion and describing engines fitted with one of these quick-starting devices as "cold starters" Such a description is intentionally misleading, as the engine in question has all the characteristics and efficiencies of a semi-diesel.

The true cold starter starts solely on the heat of compression, which is sufficient to ignite the charge with a cold engine.

(*b*) The semi-diesel suffers from either cooling off of the hot bulb at light loads or overheating of the hot bulb at full loads, according to the compression pressure that the engine was designed for (150-250 lbs. per square inch).

Both these faults can be met by special devices which, however, all entail *hand adjustment* by the engine driver for efficient running. This is always an undesirable feature.

The prevailing modern type of semi-diesel is the two-stroke vertical, usually using crankcase compression. (The old 4-stroke type has deserted practically *en bloc* to the cold starter camp).

This type of engine, until the advent of the cold starter, kept its market, not by its efficiency as compared with the diesel, but by its simplicity, low first cost and light weight. It is only found in the smaller sizes from 5 h.p. up to 6 cylinder 480 h.p., 80 h.p. per cylinder marking the limit at which it is possible to use the air-cooled piston.

Up to date no two-stroke cold starter has been evolved from the corresponding semi-diesel 2-stroke in this country, but the manufacturers of the latter are at last realizing that they must move with the times in face of intensive cold starter competition. One of the leading two-stroke semi-diesel firms has announced that it is building an engine with a higher compression pressure (280-300 lbs. per square inch). The engine is fitted with an electrical quick starting device and the higher compression pressure enables the head to be entirely water-cooled. It is not a cold starter but is a step in that direction.

As regards running characteristics the principal points are summarized below.

(1). *Range of fuels.* The semi-diesel will run most satisfactorily on the light residual oils of about .88 to .9 specific gravity. Although

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the makers claim that their engines will run on fuels up to .95 specific gravity they are careful to avoid stating that their maintenance troubles will probably be doubled thereby.

(2). *The fuel oil consumption* of semi-diesels is poor as compared with its rivals, ranging from .48 (exceptional) to .55 lbs. per B.H.P. Hour with oil of approximately .88 to .9 specific gravity and 18,500 B.Th.U's per lb.

By substituting a separate scavenge air pump for crankcase compression (big diesel practice invariably has the separate pump) both the fuel and lubricating oil costs are cut down, at the expense of simplicity and first cost.

(3). *The lubricating oil consumption* is very high, especially in those types using crankcase compression without forced lubrication. The consumption varies from 1½ to 2½% of the fuel oil consumption.

(4). *The first cost* is very low, lower than either the diesel or cold starter.

(5). *The maintenance and attendance.* Provided too cheap and heavy an oil is not used, maintenance of these engines is simple. The engines are easy and safe to handle with moderately skilled attendance.

Fig. (1) shows the cylinder head of the Tangye semi-diesel.

Leaving out the intermediate types of engine, it is found that the land type of cold starter is a four stroke semi-diesel which has been altered as follows :—

(1). The cylinder head is entirely watercooled and the compression pressures raised to 380 to 420 lbs. per square inch. At these pressures no quick starting device is necessary, as the heat of compression is sufficient to give reliable starting under all conditions.

It should be noted that 380 lbs. per square inch is the limit, and as a precautionary device with engines working at that pressure it is quite usual to find a hot tube in the cylinder head which in an emergency can be heated up.

(2). At the same time, if the plain constant volume cycle were retained the maximum explosion pressures developed would be excessive. The timing of the fuel pump cam is therefore set a little later than in the semi-diesel, so that the fuel is burnt partly at constant volume, up to about 560 lbs. per square inch in the land type, and the remainder at constant pressure, which explains the rounded top to the indicator diagram. Even so there is a marked thump in these engines on heavy loads.

(3). The same principle of injecting the fuel by fuel pump and pulverizer, known as solid injection, is retained, but improved to

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give finer atomization, using in the land type fuel oil injection pressures of 1500-3000 lbs. per square inch.

(4). Whereas semi-diesels are not usually fitted with compressed air apparatus for starting under 15 h.p., the apparatus is common with all types of cold starter. Engines can be got away with air pressures of 60 lbs. per square inch, but 250 lbs. per square inch is the normal pressure used.

Fig. (2) shows the cylinder head of a Blackstone cold starter. Comparing with Fig. (1) it will be noticed that the protuberance on the piston head has been retained. This is known as a "turbulence block" and is a feature of all land type cold starters except in some of the larger sizes.

Its object is to provide a state of turbulence in the ante-chamber at the moment of injection of the fuel. Air, trapped in the spaces AA, is forced at high velocity into the ante-chamber at the end of the compression stroke, thus attaining this object.

The greatest disadvantage of solid injection is that, unlike air blast fuel injection, it does not provide good turbulence. Hence it is usually found that the turbulence, and therefore efficiency of combustion, falls off as the piston starts to move out, i.e., during the constant pressure portion of the combustion. This probably accounts for the coloured exhaust of a cold starter, which gets more pronounced as the load, and, therefore, the constant pressure period of combustion, increases.

Two questions naturally arise on reading the foregoing. (1) Why the variation in fuel oil injection pressures from 1500-3000 lbs. per square inch? (2) Why the variation in compression pressures from 380 to 420 lbs. per square inch? (1) The oil when issuing from the pulverizer comes out in one or more fine jets which split up into a mist at a distance from the pulverizer, which depends on the pressure with which it is forced through the pulverizer. For the marine cold starter pressures up to 9000 lbs. per square inch are used. In that case the oil spreads out in a mushroom shaped mist immediately on leaving the pulverizer holes. With pressures of 1500 to 2000 lbs. per square inch the oil will travel as a jet some distance before spreading out as a spray.

The aim is to spread a mist of fuel out all over the combustion chamber and not localize it round the pulverizer nozzle nor let it impinge as a jet or jets on the combustion chamber wall.

The pressures used, therefore, are designed to suit the shape of the combustion chamber.

As regards the compression pressures these are mainly governed by the manufacturers' own ideas as to what will give reliable cold starting. The lowest pressure possible is used to simplify construction and lower bearing, etc., stresses.

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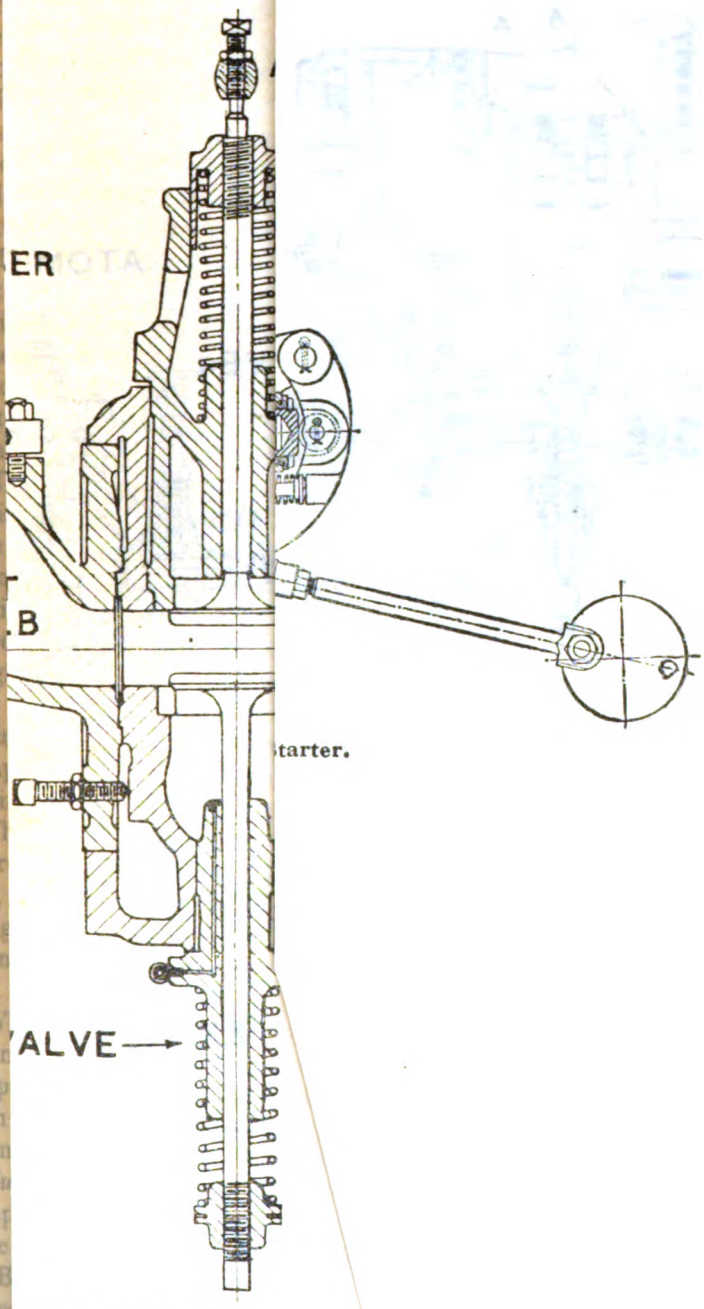

i-Diesel Engine.

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The facts and figures regarding the cold starter are enumerated under the heading of Marine Cold Starters.

Turning to the diesel engine, as is well known, this engine uses a compression pressure of 450 to 500 lbs. per square inch. The normal method used for injecting the fuel is by means of a blast of air at 600 to 1000 lbs. per square inch pressure.

It is on account of the cooling effect of the air blast that a diesel has to use a higher compression than a solid injection engine of the cold starter type, in order to compensate for the loss of temperature.

In order to avoid excessive pressures the fuel is burnt approximately at constant pressure.

The diesel engine is made in a large number of different types on both the four-stroke and two-stroke cycles. It is made multi-cylinder double acting, single acting, opposed piston and many other special types from 35 h.p. up to 7200 h.p. Orders have just been placed for an 8,000 h.p. 8 cylinder marine diesel. With air-cooled pistons the limit of B.H.P. per cylinder is 175. With water-cooled double acting pistons 750 S.H.P. has already been obtained.

The diesel engine is now slowly but surely ousting the reciprocating steam engine from marine work up to 10,000 H.P. Over this size it cannot compete with the steam turbine. The whole problem before diesel makers now is (1) to simplify and (2) to lighten their engines. (1) will be dealt with later. As regards (2) the limit of development has now probably been reached with the four-stroke single acting engine. Future development of high powers with low weight for power undoubtedly lies along the lines of the double acting two-stroke with supercharging.

Apart from marine work there is a certain scope for this type of engine for stationary purposes.

The diesel engine using air blast fuel injection has the following characteristics. *Fuel oils used.* Diesel engines can use the heaviest oils, up to tar oils, with the aid of pilot ignition. Engineers, however, are generally in agreement that the increased maintenance troubles are not worth the increased economy of using the heavier and cheaper oils.

When the heavier oils are used, a practice known as "centrifuging," for getting rid of the solid impurities in suspension in the oil prior to its use, is advisable.

In all cases the heavier oils have to be preheated in order to get them to flow to the fuel pump.

Fuel oil consumption. This is extremely good. A fuel oil consumption of .37 lbs. per S.H.P. hour has been recorded with a very large marine diesel. More normal figures range from .42 to .48 lbs. per B.H.P. hour with fuel 18,000 to 18,500 B.Th.U.'s per lb. *Lubricating oil consumption* is much lower than in the semi-diesel, being in the nature of .0002 to .0006 lbs. per B.H.P. hour—approximately

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½ to 1½% of fuel consumption. *First cost.* The diesel first cost is very high. It is difficult to give actual figures, but Kemp's pocket book gives £25 to £30 per B.H.P. at makers' works. *Maintenance and attendance.* For the engine to be run with safety and economy highly skilled attendance and very careful maintenance are necessary. It is, therefore, not suitable for general army purposes.

As mentioned before, the chief problem before the diesel manufacturer was to simplify his engine.

The obvious point of attack was the high pressure air blast used for injecting the fuel.

While producing an excellent condition for combustion in the cylinder head, it has the following drawbacks.

(1) Its cooling effect necessitates a very high compression pressure. These high compression pressures necessitate heavy construction and, therefore, low mechanical efficiency, to cater for a possible pre-ignition and consequent high explosion pressure.

(2) The air blast necessitates a compressor running continually and a blast air storage bottle. These both add to the first cost and overall weight and bulk, and the former is a source of danger and lowers the mechanical efficiency.

(3) Unskilled or careless attention to the fuel valve and blast air arrangements have resulted in more than one disastrous explosion.

(4) The air blast pressure for economic running requires continual regulation with the load and engine speed. This leaves the efficient running of the plant largely at the mercy of the engine driver.

Some diesel manufacturers, therefore, now make both air blast and solid injection engines. Many more are experimenting with solid injection.

This type of cold starter having been developed from the diesel is very often known as the " solid or mechanical injection diesel." As far as constructional detail goes it follows diesel practice in everything except the fuel valve, even to the flat top or concave diesel piston head. It does not use the turbulence block in favour with the land type of cold starter and injects the fuel straight into the cylinder head, as in diesel practice, and not into an ante-chamber as in land cold starter practice.

In consequence, as already mentioned, fuel oil injection pressures of 4000 to 9000 lbs. per square inch are used, which pressures are very hard to deal with as far as pump packing, etc., is concerned.

Whereas with the air blast compression pressures of 450 to 500 lbs. per square inch are necessary, owing to the cooling effect of the blast, with solid injection the pressure is dropped to 420 to 450 lbs. per square inch. The fuel, as in the land type, is burnt partly at constant volume only up to higher pressures, in some cases, pressures from 560 to 650 lbs. per square inch being met with.

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The efficiencies of both the land type and marine type cold starter are about the same, and the following facts apply to both.

Range of sizes. Marine types are only made in fairly large sizes. The Vickers firm make from 450 S.H.P. up to an 8 cylinder 2700 S.H.P. type. They are made 4-stroke or 2-stroke. Land types are only made from 10 H.P. single cylinder up to 950 H.P. 6 cylinder (the limit with air cooled piston 4-stroke cold starter or diesel is 175 B.H.P. per cylinder); only the single acting 4-stroke type has been developed at present.

Fuel oils used. Identical with the diesel.

Fuel oil consumption. Test bed consumptions on a land type engine have been got down to .365 lbs. per B.H.P. hour with fuel of 18,500 B.Th.U's per lb. A more normal consumption ranges from .4 to .48 lbs. per B.H.P. hour. This compares very favourably with the diesel.

Lubricating oil consumption. Identical with the diesel.

First cost. Intermediate to the diesel and the semi-diesel.

Running costs. Taking into account everything, including depreciation, the balance is in favour of the cold starter as against either the diesel or the semi-diesel.

Maintenance and attendance. The engine is simple and safe to handle with unskilled labour. Its maintenance troubles are very little, if any, more than a semi-diesel's and much less than a diesel's.

The foregoing should prove that the oil engine future lies in the cold starter type.

Three new fields of use have been opened up to heavy oil engines by this type.

(1) Aero engines. Little has been done in this line at present. Messrs. Beardmore and Co. exhibited a 6-cylinder 600 B.H.P. 1300 r.p.m. cold starter at Wembley, the weight working out at 3 lbs. per B.H.P., but this is still experimental.

(2) Automobile engines. Continental manufacturers have tackled the problem and obtained speeds up to 2,500 r.p.m. and maintained them. The difficulty is in this case to obtain sufficient flexibility, and the great advantages are the enormous saving of fuel costs and the absence of fire risks.

(3) Railway locomotives. Experiments are being made in this direction, but the only field of application would appear to be in tropical countries where water and coal are scarce, e.g. East Africa. Also they would appear to have possibilities for active service use.

To conclude, while no more improvement in blast air injection can be looked for, there is still room for improvement in solid injection.

The brake thermal efficiencies of the air blast diesel and the cold starter are about the same. The diesel mechanical efficiency is

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73 to 75%, due mainly to the work absorbed by the compressor. The mechanical efficiency of the cold starter is 85%. The indicated thermal efficiency, therefore, of the cold starter is some 10% worse than that of the air blast diesel, showing that *per se* solid injection is not yet comparable to air blast injection. Experiments made in an endeavour to raise the mean effective pressure of heavy oil engines at high speeds have demonstrated that a much higher M.E.P. can be obtained at present with air blast fuel injection than with solid injection.

As it is desirable for instructional purposes to find some simple definition of a " cold starter " the following definition, on the lines of those got out for the semi-diesel and diesel by the Diesel Engine Users Association, is suggested.

A " cold starter " is a prime mover actuated by the gases resulting from the combustion of a hydro-carbon oil. A charge of oil in a fine state of subdivision is injected into the engine cylinder at or about the time of maximum compression, the oil being injected by the pressure exerted on it directly or indirectly by a cam-operated fuel pump.

The heat of compression is the sole means of igniting the charge at all times. There is no uncooled portion of the cylinder head. The engine is capable of starting on residual oil of .9 S.P.G.

Combustion takes place partly at constant pressure and partly at constant volume.

Fig. 3 shows comparative indicator cards of the semi-diesel, cold starter and diesel.

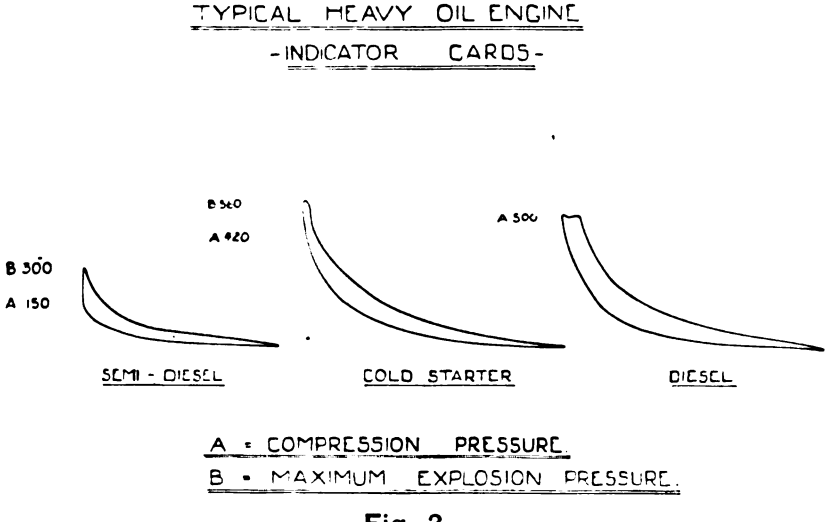

Fig. 3.

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NOTES BY A CHIEF ENGINEER DURING THE GREAT WAR OF 1914-1918.

By BRIGADIER GENERAL W. BAKER BROWN, C.B.

ALTHOUGH much has been written about the details of the various campaigns which made up the Great War of 1914-18, little has been published about the work which was done almost unnoticed in the Commands at Home and in the Colonies. This work in preparing the components of the Field Armies and in holding the bases used by our Fleets was essential to the efficiency of the mobile forces afloat and ashore, and will have to be done over again if we are ever faced with another war of the same magnitude. A record of such work may, therefore, be useful as well as interesting.

The outbreak of war in 1914-18 found me employed as Chief Engineer in the South China Command and stationed at Hong Kong, where I had joined in January, 1914. The G.O.C. of the station was Major General F. Kelly, C.B., late R.E. (and no one could have wished for a better chief). The station was well known to me as I had served there in command of the submarine mining company from 1901-1904, and on the outbreak of the Russo-Japanese War in 1904, I had been employed for two months on the staff of Major General Villiers Hatton, C.B., in revising the defence scheme. One of the outcomes of this revision had been a recommendation for a considerable increase in the Light Gun and Electric Light Defences and in the provision of military roads to the passes on the Kowloon hills. The station's recommendations were adopted by the War Office and were in full progress when there occurred the violent swing of the pendulum which accompanied the transfer of the mine defences to the Navy in 1904 and 1905, and which culminated in the appointment of the "Owen Committee." This Committee, which was perhaps the most iconoclastic of any of the long series of Committees which has studied the question of our defences, adopted the extreme naval view that the advent of submarine boats would render all our harbours liable to underwater attack and would thus render useless all the anti-torpedo boat defences. In pursuance of this view, the Committee recommended the withdrawal of all guns smaller than 6 inch, and many of the defence lights. At the same time they considerably increased the heavy armament. During the years following 1905 the various alterations and additions recommended were carried out.

But by 1913 it had been found that the development of submarines had not followed the lines anticipated by the naval experts of 1904,

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and that so far from small submarine boats being developed for transport on board parent ships, the tendency was to make these boats larger and larger, so that they should be more seaworthy. In fact, their development followed very closely that of the torpedo boat, which, begun as a small armed pinnace carried on board ship, has developed into the present sea-going "destroyer." Coupled with the increase of size of the submarine, it was found that ample depth of water was essential for safe navigation, with the result that in harbours like Hong Kong, which has a maximum depth of only five fathoms at low tide, it would be impossible for a submarine to enter and manœuvre except on the surface.

The attack was thus compelled to revert to the old surface methods, trusting to high speed and darkness to get home. In short the pendulum was on the reverse swing and steps were being taken at all ports to introduce again a close defence of 4.7 in. and 12 pr. guns combined with obstacles. The first half of 1914 was thus taken up in preparing schemes for new batteries or for alterations of old ones, and the outbreak of war found us with several new batteries just commenced.

One of these was of a rather unusual character, and as it was never completed may be described as a sample of the jobs which occasionally have to be tackled by a military engineer. This battery was one for two light guns which had to be mounted on the south end of Kowloon peninsula to cover the approaches to the dockyard from the west. This end of the peninsula had been only recently reclaimed from the sea and was a dead flat site at a level only a few feet above high water—mark. The guns had to be mounted 45 feet above high water mark so that automatic sights might be used, while the War Office had calculated the energy of the recoil as equivalent to a dead load of 1,000 tons for each gun applied at right angles to the centre line of the towers which were to carry the guns. As this far exceeded any strain which could be produced by the dead weight of the building or the guns, the calculations for the towers were the same as for a cantilever 45 feet long with a weight of 1,000 tons at the end. The foundations gave some trouble; the first suggestion was to put the towers on the edge of the reclamation, but investigation showed that the whole site which had only recently been reclaimed was enclosed by a wall of "pierres perdues" or large blocks of natural stone piled in a loose heap, and that behind this there was a filling of soft soil which was 30 feet deep. It was thus necessary to bring the towers back some feet from the front, and after some consideration, the only available site which gave the necessary area of view was astride of the main road and close to the pier used by the ferry boats. To comply with these conditions the final design of the battery took the form of an ornamental gateway across the road. On each side was a tower

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with a gun on the top and with three storeys below; the shells being heaviest were put on the ground floor, the cartridges over and the gun stores above. Between the two towers was placed a two-storey gateway which formed living quarters for the gunners, with cooking and ablution, with an observing post for the officer on top. Ample head room was left underneath for a double line of traffic in the roadway and two footpaths.

The foundations were made on a series of piles, each 36 feet long, of a species of timber obtained from the Straits Settlements; the tops of these were to be joined by a cross lattice of steel girders to which were attached a series of steel rods for reinforcement of the walls of the towers and a steel framework to support the centre. The tops of these foundations were to be bedded in a heavy raft of concrete and the towers built up of concrete so as to be homogeneous, a proportion of the reinforcing rods being turned in at each floor. Loopholes were to be provided for close defence. Such a form of construction would not only have been impervious to bullets, but even to light gun fire. Before the construction had risen above the foundations the altered situation, created by the withdrawal of the German Fleet, made further progress unnecessary.

Besides these defence works which were in hand, the special measures taken on the outbreak of war which affected the R.E. were accommodation for the garrison at their war stations, a camp for war prisoners and the preparation of the field defences. The accommodation for the garrison was not a difficult job, as the Chinese are past masters at erecting the "mat shed" hut, and all details for this had been threshed out in the defence scheme. The accommodation of war prisoners gave more trouble. No great number of these had been expected, but provision had been made in the defence scheme for forming a small camp for about 50 prisoners on Stonecutters Island, which is about three miles by sea from the headquarters and is occupied solely by the military. It was thought that not only would the prisoners be safe here, but that they could be guarded by the local garrison of artillery and infantry. These forecasts proved wrong.

In the first place the number of prisoners was much larger than we had expected, and thereby hangs a tale.

In the long controversy which accompanied the growth of the submarine mining service*, one of the objections often made by naval officers to the use of mines was that they would unduly restrict the entrance of ships and cause an accumulation of shipping outside a port. The answer to this was that there is no free entrance or exit for vessels in and out of a port even in peace time, as strict rules are always enforced to regulate the use of anchorages and to enforce quarantine. The examination of vessels in war time would therefore

* For details of this see *History of Submarine Mining in the British Army*, chap. V.

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only differ slightly from the examination necessary to enforce quarantine laws, the only important difference being that it would be necessary to carry out the first inspection of vessels in selected areas outside the defences but within the limits of gunfire.

To get at the facts, when revising the defence scheme in 1904 I analysed the traffic entering Hong Kong Harbour in 1903 with the assistance of the Harbour Master, and got the following rather astonishing data, considering that Hong Kong handled at that time more traffic in and out in a year than any port in the world.

As regards steamships, we found that an average of 18 steam vessels entered the port daily, of which 6 used the eastern or deep water entrance and 12 used the western or shallower entrance.

There were also about 50 junks entering daily exclusive of fishing boats.

It was obvious that the inspection of this amount of traffic offered no particular difficulty, and so it proved when we had to put the procedure in practice. Among the appointments made in the defence scheme was that of an Assistant Provost Marshal, for which a retired officer living at Hong Kong was selected. This officer accompanied the harbour officials on the visits to ships arriving and inspected all the passengers, throwing on the latter the onus of proving that they were not Germans. The result was that we picked out a number of German reservists from Manilla and other places, and this caused a steady movement into our prisoners' camp from all vessels arriving, necessitating the opening of an extra camp on Stonecutters Island and an addition to the infantry garrison to find the necessary guards. As the water supply on this island is entirely dependent on rainfall on a small catchment area, we were at once somewhat anxious about water supply. At the same time the A.P.M. found the distance of the camp from Headquarters was very inconvenient. I therefore obtained the approval of the G.O.C. to make a new camp on the mainland at the end of the Kowloon peninsula, close to the barracks and landing pier and readily accessible from all parts. To provide for all contingencies, I laid out this camp of a size to take 1,000 prisoners and erected huts to accommodate 500. This was fully justified when a few weeks later we got orders from home to intern all German residents of Hong Kong who were physically fit and to expel their families. This order resulted in an addition of nearly 300 prisoners to our numbers, or about 350 in all.

The field defences of Hong Kong have been the subject of much controversy, on account of the large perimeter to be covered. The harbour is situated between the mainland of China and the Island of Hong Kong, and has a length from east to west of about 10 miles. The backbone of the island is a line of granite hills with heights of from 1,000 to 1,800 feet rising steeply from the south shore of the

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harbour. On the side of the mainland there is a similar line of hills rising to over 2,000 feet and about 4 miles from the harbour. Adding the width of the openings at each end, the perimeter of the whole was about 30 miles, of which 4 miles was water and the rest rough hills covered with boulders and trees. To facilitate movement along these hills a system of military roads had been gradually constructed, giving access to all the principal gaps and also forming a link along the line of hills on each side. The garrison of Hong Kong, which included five infantry battalions and some mobile guns, was large as such garrisons go, but was obviously insufficient to hold such a perimeter in force. On the other hand, the German forces in the East were quite insufficient to attempt any attack in force, and the most we had to meet were raids by small landing parties, directed against important points such as the defences of the entrances. Such attacks might have had the effect of keeping our naval force in the East tied to those waters, but would not seriously affect the final result of the war. If such attacks were contemplated it was obvious that they would be most effective immediately on the outbreak of war, so that in the defence scheme at all defended ports provision was made to commence selected defences immediately on the commencement of the "preliminary stage." With this in view schemes were kept prepared, tools and materials were held in readiness by the A.O.D. and the resources of civil contractors in the matter of civil labour and materials were reviewed periodically.

We received the preliminary telegram announcing a probable war against an enemy "unnamed" on Thursday, 30th. July, 1924, and the defence scheme was put in force at once, accordingly to plan and with very little trouble. The principal difficulty was to persuade the infantry portion of the garrison to take the work seriously, two commanding officers suggesting to me that as the men had moved to their posts on Friday, and Saturday was a half day and Sunday a holiday, it would be sufficient to commence digging on Monday.

The only detail which gave me any anxiety was the close defence of the heavy batteries recently constructed, many of which were quite open on the land slide. There had been considerable discussion about this, and there was a definite conflict of opinion as to whether such defences must be pushed out so as to keep attackers at a distance ; or whether a close defence would not be more effective, especially at night. No decision had been reached by the War Office on this, but personally I plumped for the close defence with a short field of fire as requiring less garrison and being well within the limits of the tools and materials available, and work on these lines was put in hand at once.

We received official notification of the Declaration of War against

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Germany on Wednesday morning, 5th August, and thenceforward were in daily communication with London, getting orders and instructions and a summary of the fighting intelligence as if we were in an English fortress. The full scheme of defence then started into full life, and the garrison settled down to war routine. At headquarters, except that a staff officer was on duty night and day, there was little change from our ordinary routine, as all officers lived so close to headquarters that the G.O.C. did not consider it necessary for officers to sleep in their offices except in the event of an attack.

The military telephone lines had all been got ready beforehand, and the only details to be carried out on mobilization were the distribution of instruments and operators to the outlying stations and look-out posts, a matter which took only a few hours.

The manning details of the electric light defence to supplement the local detachments also went out at once and all electric lights were run continuously.

Hong Kong was in the happy position of possessing a strong and efficient Volunteer Corps which included Engineers, Artillery and Infantry. These were called out. It was, however, found necessary to give a number of exemptions, as motives of patriotism had caused all the leading English officials to join the Corps, including the Colonial Secretary and Chief Justice. It was obvious that these gentlemen would be more usefully employed at their ordinary occupations. As time passed it was evident also that it was not in the interests of the Colony to keep the best of the business men permanently at military duty. Arrangements were therefore made to work a system of relief.

In the case of the manning details for the electric lights, advantage was taken of an offer made by certain residents to give partial service, and under this over 50 very useful recruits were enlisted who undertook to take a " watch " of 8 hours every third night. Most of these had some technical qualification and easily picked up the work required from them. When, later on, the bulk of the regular R.E. were withdrawn from the Colony, this local force maintained an efficient service of lights.

Some exciting and amusing incidents occurred in connection with the control of traffic. Among the first vessels to attempt to enter the port after the declaration of hostilities was a Chinese gunboat from Canton, which steamed gaily in towards her usual anchorage. As she disregarded all signals she had to be pulled up in the historic manner by a shot across her bows. The first shot was rather wide and produced no effect, but the second shot dropped so close in front of her bows that the vessel ran into the splash produced by the shot. The cold douche was effective. Another incident had a tragic ending. A Japanese cargo boat arriving about a week after war commenced took no notice of three shots fired across her bows,

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so the officer responsible put a plugged shot through the fore part of the vessel. The shot went right through, doing little structural damage. Unfortunately, one of the seamen was in the line of the shot, and suffered accordingly. At the subsequent Court of Inquiry the Japanese Captain explained that he had left his last port before he heard war had been declared, and apologised for the trouble he had given.

All this time the centre of interest was our Fleet, which was under the command of Vice-Admiral Sir T. Jerram, K.C.B., who had the reputation of being one of the best tacticians in the Navy. On the outbreak of war the Fleet was up at Wei-hai-wei for the usual summer exercises, being fully equipped, as was always the case, with ammunition and fuel, and ready for immediate service. As Wei-hai-wei was usefully placed for co-operation with our allies the Japanese, and for watching the German port of Kiauchau, the Admiral proposed to stay where he was, leaving the military garrison to hold Hong Kong; but orders were received from the Admiralty for the Fleet to return to its base to pick up the battleship "Triumph," which was held in reserve at Hong Kong. In order to man this ship, and also some merchant ships which were commissioned as auxiliary cruisers, it was necessary to recall to Hong Kong the numerous river gun-boats which are maintained by us for police duty on the Chinese rivers. And as these did not give the numbers required, some R.G.A. and Infantry were drawn from the garrison, reverting to the practice of the Napoleonic wars. This preparation took some time, and meanwhile touch was necessarily lost with the German fleet. Subsequent events, however, showed that this fleet had never any intention of challenging our forces, and with the exception of the *Emden*, all the German ships crossed the Pacific to take part later in the battle of Coronel and to be annihilated at the Falkland Islands. It is rather difficult to see what they could have hoped to gain by this concentration, while the career of the *Emden* showed what damage could be caused by a free-lance on our lines of communication. Once our fleet left the harbour the fog of war descended and covered their movements, and I next saw Sir T. Jerram at Singapore in January, 1915, in command of a fleet composed of two French, two Japanese, two Russian vessels and a small British gun-boat, all the larger ships of his fleet having been withdrawn for service elsewhere.

With the large German element in the Colony, the enforcement of an adequate censorship was unusually difficult. For obvious reasons I cannot dwell on this. But I may mention that we had ample proof that the German missionary organisations in China were largely used in the dissemination of military intelligence. When, as explained above, we got orders to expel or intern all Germans, all their missionary organisations were compelled to leave.

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The defence once secured, our thoughts naturally turned to offence and to possible action against German forces in the East. These forces centred in the port of Kiauchau, which was held by the Germans since 1898 and had been carefully fortified on both the sea and land fronts. In addition to the garrison of this port the Germans had an armed force in the town of Tientsin, where the German concession lay alongside that held by ourselves. In the same town there were military garrisons maintained by the British, Japanese and Russian forces, our own force being commanded by a Major-General under the direct control of the War Office. At Shanghai, the port for the centre of China, where there is a large European settlement, there are no regular troops, but there is a strong volunteer force of mixed nationalities, including German and Austrian. This force was commanded by a regular British officer, and was inspected annually by the G.O.C. in S. China or an officer deputed by him. A few days before the outbreak of War all the German Reservists in the East were ordered into Kiauchau, and those from Hong Kong and ports in North China succeeded in getting there, though, as related above, we succeeded in catching many of those from Manilla and neighbouring Islands. The regular German garrison of Tientsin also moved by train to Kiauchau, their concession being occupied by the British. This increased the German garrison of Kiauchau to a strength estimated at 7,000, rather too much for the united garrisons of Hong Kong and Tientsin to tackle unaided, but not an impossible proposition if a little help could be obtained from India. The entry of Japan into the war changed the entire situation, and when she expressed her intention of dealing with Kiauchau, nothing was left for the discussion except details. It was early decided that Hong Kong would have no part in the coming operations, much to our disappointment, but in order to emphasise our alliance with Japan, the G.O.C. Tientsin joined the Japanese force with an "armed escort" of one British battalion and a wing of Indian Infantry. This force had no artillery and was entirely dependent on the Japanese for transport. The British fleet was to co-operate by keeping the sea defences busy, and one of the first things we heard of the operations was the arrival of two torpedo boat destroyers in Hong Kong who had ventured too close to the German guns and had to return to their base to repair damages.

When operations commenced, the Japanese, who had sent a completely equipped force, naturally dominated the operations, and when the German outposts were driven in on the line of defences the little British force was allotted a portion of the line near the centre, between two of the German forts. On the night of the main attack, the British force was ordered to advance against their portion of the line, were held by the Germans and sustained some casualties. The G.O.C. then called on the Japanese for assistance

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from the guns and held on to what he had got. Meanwhile, the Japanese had launched their attacks all along the line, had captured all the German forts and occupied the town. The British force marched in a few hours later.

Just before the main attack, the German steamships in the port tried to escape. Seven of them were picked up by our fleet and sent as prizes into Hong Kong.

The capture of Kiauchau confirmed the fact that the German fleet had left the West Pacific, and henceforward the centre of interest was the *Emden*, which played a sporting game with great skill and some luck, until she met her fate at Cocos Island. She had managed to sink some of the ships with supplies for Hong Kong, but not enough to seriously interfere with our routine.

Once she was dealt with, the War Office began a systematic weeding out of all the British officers and men in the Eastern garrisons, replacing them by retired officers and by territorial and Indian units.

In November we sent home the 25th Coy. R.E. and a large draft of the N.C. officers and men and individual officers and men left every week for England. My own turn came in January, and I left on a P. & O. steamer with many officers and men of the regular forces and a large contingent of Volunteers for service drawn from all the Eastern ports.

At Singapore, we took on more, including the G.O.C. and his staff, and at Ceylon we all transferred to one of the largest P. & O. steamers which had on board the officers and crews of the flag-ship on the Australian station and also a large group of volunteers from Australia to join the Army at home.

At Aden we heard of the mutiny of the Indian troops at Singapore, and at Suez we heard of the first naval attack on the Dardanelles. I ventured to remark to a Captain R.N. that in attacking land defences without the assistance of a land force the Navy were running counter to all professional opinion of pre-war days, and on arrival at Port Said he told me that troops were coming out and that some of his officers were being left behind to act as landing officers. Together we considered what sort of force was coming out to fight the whole Turkish Army, as they would inevitably have to do. On arrival at Marseilles we heard that the British force was to be composed of three Divisions with some French troops, and I concluded that the latter would include at least an Army Corps of French Colonial troops, a very inaccurate assumption as it turned out.

We arrived at Plymouth on the 8th March, 1915, to be met with the news that two german Submarines had been seen in the Channel and that all military personnel and their families were to proceed to London by train.

To be continued.

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THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914-19.

EXPERIMENTAL SECTION (*concluded.*)

CHAPTER 12. METHODS OF DESTROYING WIRE ENTANGLEMENTS.

FROM the earliest days of the war endeavours were made to devise some method of destruction of wire entanglements, so as to form a passage for attacking troops.

Many inventions were submitted to the G.H.Q. Experiments Committee from time to time. One suggestion consisted of spraying different acids from special containers. The reports of the inventor showed that it required 36 to 48 hours of spraying with mixed sulphuric and nitric acid to affect the wire, and the idea was not developed.

A wire cutter attached to the nose of the rifle was a more practical suggestion, and was occasionally used.

Some means of removing the entanglements in bulk was really needed, and experiments were undertaken with various forms of rocket apparatus. A cable with grapnel attached was thrown, and caught in the wire, which was then removed by a winding arrangement, either from the trench or by means of an armoured car.

Another method tried was to throw a charge of high explosive into the wire with a time fuze for firing.

Rocket apparatus was found too unreliable, just as it was for other purposes requiring accuracy of range and direction, and experiments were soon given up.

The Bangalore Torpedo proved the most satisfactory solution, and was used in large quantities. Various patterns were made by R.E. units, but the commonest was that designed in the First Army workshops. The Experimental Section had little to do with this, with the exception of advising on minor modifications which were introduced when, during 1918, manufacture in England was arranged for. Supplies had not begun at the time of the Armistice, so that all those used during the War were of local manufacture. At different times various mechanical devices for propelling the torpedoes forward from a trench were suggested, but no practical method was ever evolved, and torpedoes were almost invariably placed in position by hand under cover of darkness.

In June, 1917, the Experimental Section made trials with a French pattern of torpedo, but this showed no advantages over the usual type and was dropped.

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Experiments were carried out in the autumn of 1916 by the Section with a grapnel device suggested by an Officer of the Engineer-in-Chief's Staff. The apparatus consisted of a steel box with a pointed nose containing a winding gear. This was worked by a winch placed behind in the trench, and caused the apparatus to move outwards from the trench after the grapnel had been thrown on to the wire. The box could haul several lengths of torpedo behind it, and would wind itself into the wire, when it could be fired. The device, although it could traverse very rough ground with remarkable ease, did not work its way far enough through the wire to carry the torpedo where it was required, and experiments were eventually dropped in the spring of 1917.

Chapter 13. Aeroplane Height Finder Instruments.

The experimental Section made two instruments which were called for by the Lewis Gun Schools for reading heights of aeroplanes. The two patterns of Height Finder were as follows :—

(i). The pattern illustrated in Photos (4) and (5), which was introduced into the Service during 1918 for use at the Schools.

The instrument was designed to aid Instructors in Anti-aircraft Machine Gun work in estimating the heights and ranges of various types of aeroplanes. It consisted essentially of a base piece (A), at one end of which was a removable brass eye-piece (B) and at the other end a wooden frame (C). The eye-piece was capable of both vertical and horizontal movement.

The wooden frame was connected to the base piece by hinges so that it could be folded down on to the base piece for transport, or opened out at right angles to the base piece while in use. When in the latter position two hinged steel bars (E), one on either side of the instrument, automatically locked and maintained it in that position.

Six flat bars (F) were screwed to the frame. These bars were four inches apart from centre to centre. Along the top and bottom of each bar was cut a series of notches of different widths.

At the base of the frame and immediately opposite the eye-piece, in a plane parallel to the top of the base piece, was a Clinometer in a brass case (G).

The head of the tripod (H), which was secured to the bracket carrying the legs by means of a screw, was provided with a recess into which fitted the spindle of a forked bracket (J), in which the base piece was mounted in such a way that it was thereby capable of movement in both a horizontal and a vertical plane. The spindle was secured in the recess by a thumbscrew (K).

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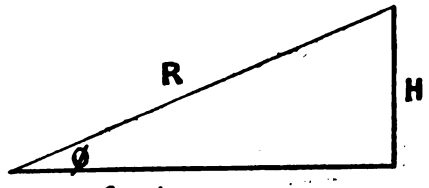
The principle of the instrument was as follows:—

At any given range, an aeroplane subtends a certain definite angle at the eye.

If a bar is placed at a certain distance from the eye and at right angles to the line joining eye and the aeroplane, the imaginary lines joining the eye to the outer edges of the aeroplane will cut the bar at two fixed points. If the distance apart of these two points is represented by a notch, the width of the notch represents the apparent width of the aeroplane at that range.

For a given angle of elevation for each range, there is only one height at which the aeroplane can be, as is obvious from the figure.



Ø = Angle of elevation.
R = Range.
H = Height.

Therefore a notch which is correct for a given range is correct at the angle of elevation φ for one height only (H).

Therefore, for one angle of elevation, a series of notches of different widths can be cut in the bar and each of these notches will be correct for one height only at that angle. Therefore, for any angle of elevation, notches can be cut which, for one type of aeroplane, will be correct for heights of 3,000, 2,500, 2,000, 1,500, 1,000 and 500 feet, and for those heights only.

For another angle of elevation, a similar series of notches can be cut, though these notches will be of different width from the corresponding notches at the first angle of elevation.

In the instrument under consideration, for practical reasons, only six angles of elevation were considered, and therefore only six bars were provided, but it was found that, if when viewed through the eyepiece the height of the aeroplane was measured on the nearest bar, the results were sufficiently accurate for all practical purposes.

The notches on the top of each bar were to be used for an aeroplane coming or going or crossing diagonally, and the notches on the bottom of the bar for aeroplanes flying directly across the front.

Conversion Tables were also prepared to enable the instrument to be used for various aeroplanes.

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Certain of the notches on the instrument were coloured red.

When using the instrument, if the notch which was found to be the correct one for use was red, the aeroplane was in, or just coming into, machine gun range.

If the notch was coloured black, the aeroplane was out of range.

The same applied also to the Conversion Tables, figures being shown in red, when the aeroplane was within range, and black when out of range.

In the Conversion Tables there were two rows of figures against each bar. The upper row represented the height in feet for an aeroplane coming or going or crossing diagonally (i.e., the top row of notches), and the bottom row represented the height in feet for an aeroplane flying directly across the front (i.e., the bottom row of notches).

(ii). A Telescope Pattern was made and demonstrated to an Anti-aircraft Committee to show that a simple type of instrument could be evolved for instructional purposes.

As it was not developed till the Autumn of 1918, no further action was taken with it, and for instructional purposes, the other pattern was simple and satisfactory. This telescope instrument was rather outside the scope of the Experimental Section's work, but was an interesting device. An ordinary Signal Service Mark IV telescope was used, and the instrument introduced at a point in the focal plane of the object glass. The principle was well known and recognised to be unsatisfactory for correct readings at heights above 6,000 feet, but was considered suitable for the purpose of correcting and instructing Machine Gunners to read heights for observation.

The Machine Gunner was hardly interested to know the height exactly, but only as to whether the aeroplane was within range or not, and 1,000 yards was considered the limit of range, i.e., 3,000 feet vertically overhead.

Owing to the various shapes and sizes of aeroplanes, practice in reading heights was difficult unless the type of aeroplane was recognised and an approximate height read off for verification.

For the purposes of the instrument, aeroplanes were divided up into four classes, and height curves were plotted and reduced to scale for each class. Two wires let into the body of the instrument carried on sliding bars could be moved towards or away from each other by rotation of the wheel on the spindle carrying the bars. Mounted on the rotating spindle was a sliding drum carrying the four graphs. A fixed pointer at the other end of the instrument was carried on a clinometer, and indicated directly the height of the aeroplane by its position in relation to the curves on the drum. The clinometer gave the angle at

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which the instrument was held, and the sliding drum indicated the distance apart of the two hairs on the width of the aeroplane, i.e., when the angle and the width had been both read, the height was given direct on the curve. By measuring the width of the aeroplane, as it flew, the heights were read off directly by the positions of the pointer on the drum. A damper was fitted to the clinometer to lock it after reading the width, so that it should be held at the angle at which the width was read. The drum could be rotated independently to bring the desired graph into place, after reading the width, and observing under which class the type of aeroplane came. A few feet in error in reading made very little difference to the height recorded, and, if the target was flying diagonally, the width was approximately the same as the forward view. For machines flying at right angles, where a side view was presented, similar curves in red were used for reading off the heights.

Investigation of the instruments for height finding led up to the development of a system of Automatic Sights and a large number of drawings and plans were prepared. These were only finished in 1919, and do not come within the scope of this work.

Plate No. XXIV shows the general arrangement of an aeroplane target made by the Experimental Section for use at Lewis Gun Schools.

The model target could be pulled round the octagonal track by hand, while the gunners at a fixed range would be instructed to sight on the target, the eight-sided figure giving eight different directions which the gunner would have to cope with. By rapid change of direction, the gunner would have to swing quickly over on to the forward sight, which gave excellent practice in the use of the sight.

CHAPTER 14. LEWIS GUNS.

WORK in connection with Machine Guns was outside the scope of the Experimental Section during most of the War, but in June, 1918, they took up the question of a mechanism for slowing down the rate of fire of the Lewis Gun; any such mechanism had to be capable of being rapidly disconnected should the normal rapid fire be required.

Experiments were carried on simultaneously by the Ordnance and the R.E. Experimental Sections, and at first both worked on similar lines. The device consisted of a catch, which held up the cocking handle at the end of its stroke, and connected to a rocking lever, which worked against an air cushion in a piston. Various difficulties were met with, and after considerable experiment the R.E. Section abandoned the air apparatus, and finally evolved an oil device, which proved entirely successful. This is shown on

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photograph (6) and Plate XXV. The development of this mechanism led naturally to the idea of single shot firing, which proved to be an altogether simpler and more satisfactory device. By means of it the heating up of the barrel became naturally slower, and experiments showed that the radiators and casing of the heavy Lewis Gun could be taken off and the weight reduced by 10 lbs. This ultimately developed into the light Lewis Gun, of which a number arrived for trial in March, 1919.

The Experimental Section produced a neat single shot mechanism in the shape of an auxiliary trigger, which could be clamped to the standard Lewis Gun. All the parts were pressed and stamped, and fitted in such a way that it should be possible for armourers to do the work in the Field. It was never generally introduced, owing to the Armistice. This mechanism is illustrated on photographs (7), (8) and (9). It consisted simply of an auxiliary trigger pivotted on a fulcrum pin, which was carried on two outside plates gripping the main trigger guard and kept in position by two screws; the auxiliary trigger carried the rocking stirrup, which worked over the end of the main trigger. By pulling the auxiliary trigger the stirrup was set to fire one round, and then slipped off the main trigger, so releasing the nose of the sear in time to catch the piston on its return stroke. In order to get continuous fire, it was only necessary to hang on to the auxiliary trigger, and pull it right back, as it then came in contact with the main trigger, and held it back.

The only other work done in connection with machine guns was a light folding anti-aircraft mounting; this was made with an old rifle for the stem, fitted with folding legs. When opened up, it gave a firm mounting, and it folded up very neatly. This pattern was sent to the Lewis Gun School in the Autumn of 1918, but no reports as to its employment had been received before the end of the war.

Chapter 15. Periscope and Hyposcope.

The work of the Experimental Section as regards optical instruments was almost entirely of an advisory nature, and very little was done in the way of experiment.

Trench Periscopes of all varieties were made during the earlier days of trench warfare in Army workshops, and were gradually developed on better lines by civil optical firms.

The superior patterns, more especially for Artillery work, were taken over later by the Special Works (Camouflage) Park, and were no longer referred to the Experimental Section.

The development of Hyposcopes, for use both with rifles and machine guns, went on in much the same way. The chief difficulty in the design of a hyposcope was to make it fold easily, so that it

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could be conveniently carried as part of the rifle, and at the same time be easily put in position for use. Its use was never encouraged in the British Army, except for special snipers, as it undoubtedly led to lack of confidence when firing over open sights.

Probably the best pattern produced during the War was the German one, of which, as a matter of interest, an illustration is given on Plate XXVI.

Various improvements of detail in the design of the Camera Obscura were evolved by the Experimental Section. The instrument was only introduced in France towards the end of 1917, and about twenty were received during the Summer of 1918, which embodied these improvements. Good results could not be obtained with the Camera Obscura, except in fine weather, and with good visibility. Under these conditions, objects were clearly visible up to a range of 2,000—3,000 yards. The instrument was very useful for observation purposes, in positions where it was possible to erect it. The whole view was projected on to the table without strain to the eye of the observer, and it was also easier to set up and move about than the giant periscopes which were developed by the Camouflage Park.

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Photo No. 5.

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Photo No. 6.

Photo No. 7.

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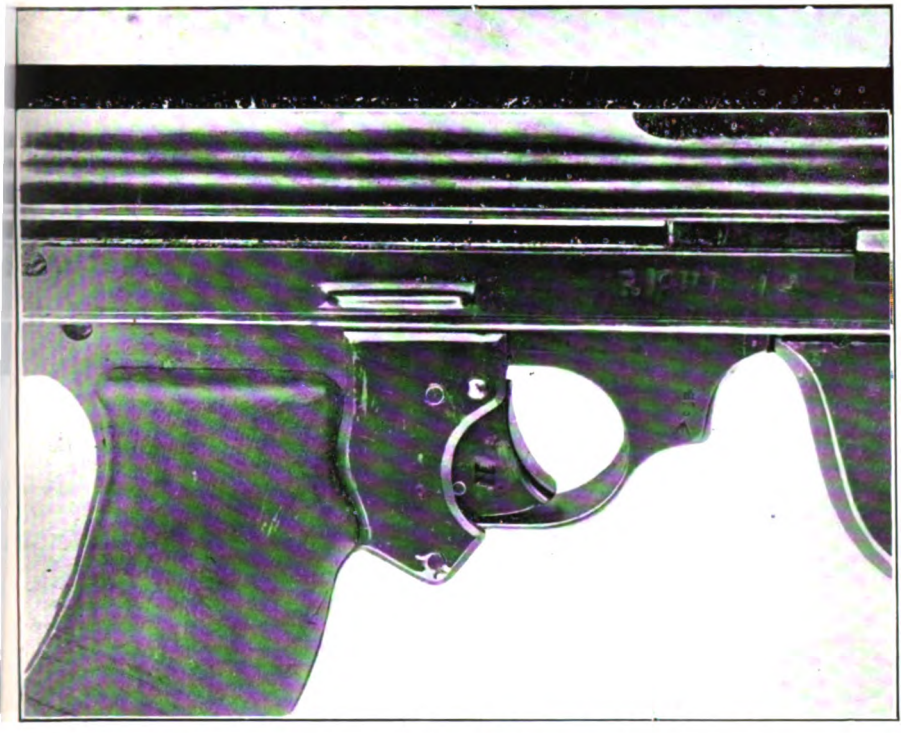
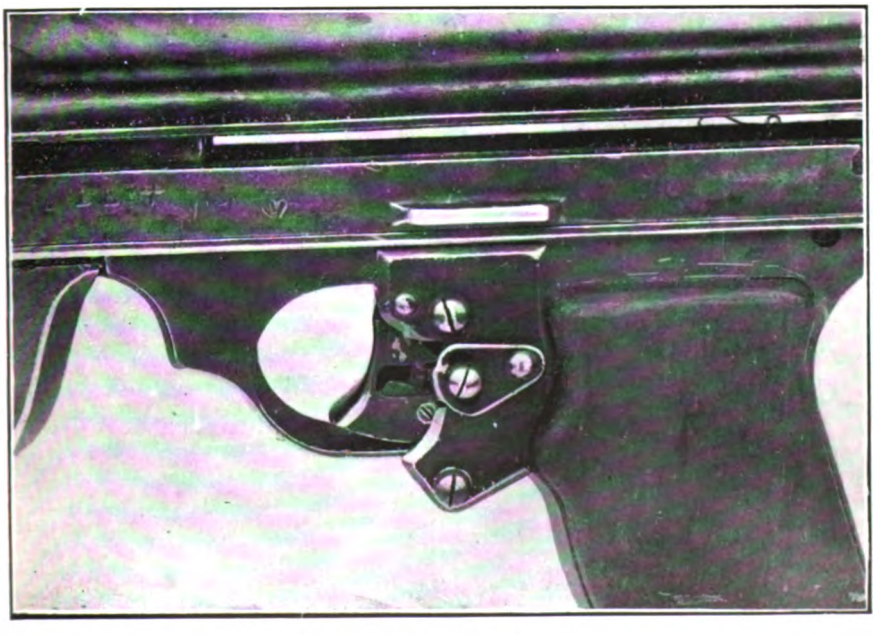


Photo No. 8.



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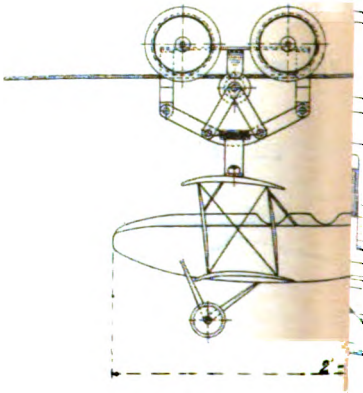

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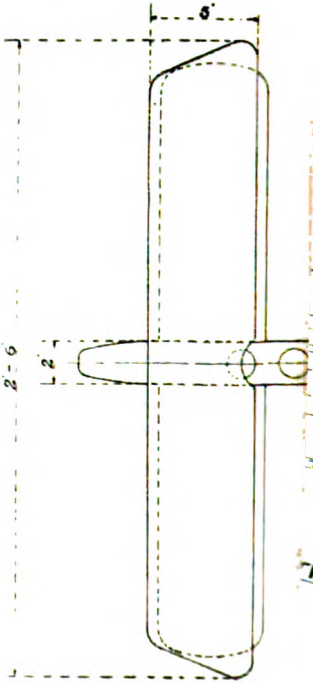

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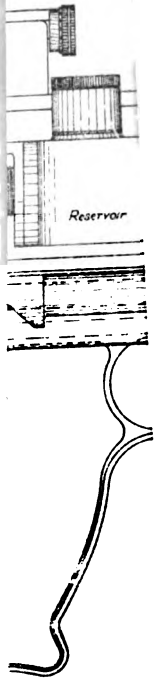
SLOWING



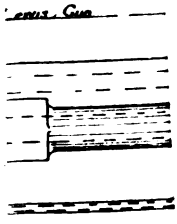


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Plate XXVI.

AND PERISCOPE.

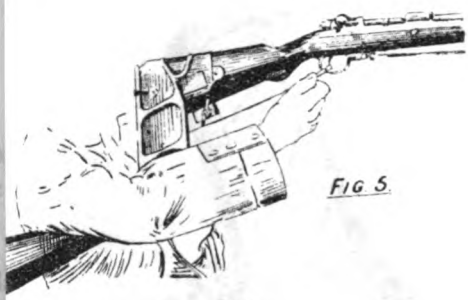

FIG 5.

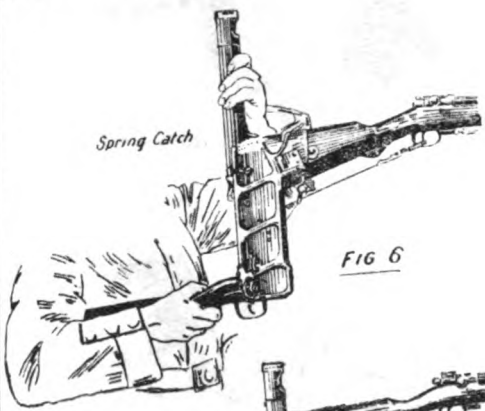

FIG 6

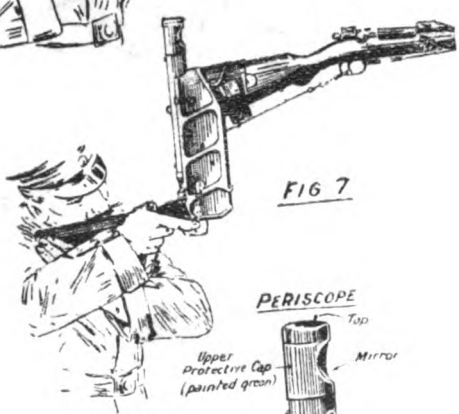

FIG 7

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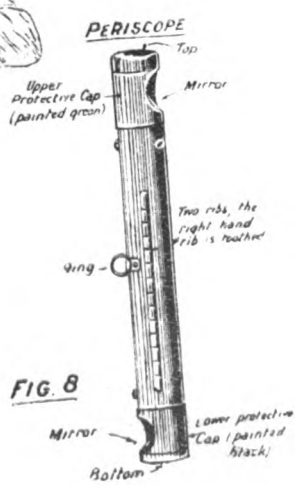

FIG. 8

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A MINOR OPERATION.

The Capture of Infantry Hill—June 14th, 1917.

By Bt.-Major I. S. O. Playfair, D.S.O., M.C., R.E.

Monchy-le-Preux marked the eastward limit of the objectives of the Arras offensive of April 9th, 1917. It stood up as a " cock-shy " for miles, and was referred to as an important tactical feature. Its north-western enclosures were reached on April 10th, and the village itself was captured on April 11th by the 37th Division, who had to repulse several counter-attacks to retain it in their possession. The 29th Division who relieved them were strongly attacked on April 14th but stood their ground. By April 15th, says the official despatch, " our front had been rolled 4 miles farther east, and all the dominating features forming the immediate objects of my attack, which I considered it desirable to hold, had passed into our possession." The offensive was, however, continued to assist the French, whose intended attack on April 9th was delayed by bad weather until April 16th.

Early on April 23rd the 29th Division gained the Western slopes of the rising ground known as Infantry Hill (see map). The attack was renewed at 6 p.m. " Very appreciable progress has been made east of Monchy-le-Preux." Further attacks were made on April 28th and May 3rd " with shallow objectives."

The British front was now roughly the line of Hill. The enemy held Hook, Long and Devil's trenches and the fortified shell-holes in and around Bois des Aubepines and between Tite's Copse and Stirrup Lane.

Towards the end of May the 76th Inf. Bde., 3rd Division, which had just been withdrawn from the Monchy area into " rest," was ordered to prepare an operation for the capture of Infantry Hill. This was looked upon by those immediately concerned as a fourth attempt to achieve what had already failed three times. The previous attacks were carefully studied. Each had been delivered after a bombardment and under a barrage, which had drawn from the enemy a vigorous reply on to all the trenches in the forward area. Hill, Dale, Shrapnel and the communication trenches Vine and Canister received particular attention, and heavy machine-gun fire developed from Bois des Aubepines and the shell-holes east of Tite's Copse. It seemed that as soon as our fire became intense the enemy opened on the above targets and rendered the handling of our supports very difficult.

Further, a study of the hours of attack showed that the enemy had every reason to be particularly alert at dawn. For example,

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on April 9 the Zero had been at 5.30 a.m.; on April 11th, 5 a.m.; on April 23rd 4.45 a.m.; April 28th, 4.25 a.m.; and on May 3rd at 3.45 a.m. Other points which received the attention they deserved were:—(1) There was as yet no wire in front of Hook, and (2) that in spite of heavy shelling the No-man's-land between Hill and Hook allowed of comparatively good "going."

The plan was as follows. There was to be a slow continuous bombardment by all calibres for 5 days, increasing in intensity each night when it was to be severe (see Artillery Programme). It was to be assisted by frequent bursts of machine and Lewis-gun fire during the night to prevent the enemy from putting up any obstacles in front of his line, and generally to keep the forward area so swept with fire that the bringing up of rations, water, stores, etc., would be very difficult, the relief of the front-line troops well-nigh impossible, and visits by senior and staff officers extremely unlikely. Particular attention was to be paid to the location and registering of hostile batteries. Fire of all kinds was to cease from 5 to 9 a.m. daily. The enemy infantry were known to be occupying shell-holes and isolated positions where supervision would be difficult; men *must* have sleep, and the only possible time to have it would be during those four peaceful hours.

The attack was to be unheralded (one can hardly say unprepared) by any fire. The attacking troops would assemble in Hill. At a given moment they would emerge and double to Hook. A proportion of men were to be "skirmishers," *i.e.*, good sprinters carrying only rifle, bayonet, 2 bombs and 20 rounds. They were expected to reach Hook before the enemy could put up any more than a spasmodic defence. It was thought that after 1½ minutes he would be awake to the situation so that a barrage was arranged to precede the advance to the second objective (The Mound and Long). The enemy would presumably open on his usual S.O.S. targets, which were well-known and therefore to be avoided. The troops advancing from Hook to Long should be clear of any artillery fire, while Hill would be practically empty.

THE ARTILLERY PROGRAMME.

Open 9 a.m., June 9th. Targets by day: Communication trenches, known and suspected machine guns, occupied and fortified shell-holes, trench junctions and headquarters. By night: General harassing fire and gassing of batteries. All fire to cease from 5 to 9 a.m. daily.

June 14th, at Zero plus 1½ minutes, intense bombardment of Bois des Aubepines, Cigar Copse, Devils Trench, Bois du Vert and The Mound. Barrage along a line north and south through the junction of Green Lane and Long. The Heavy Artillery was to neutralise batteries and fire on selected areas, assisting the Field Artillery to

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deal with certain suspected machine-guns and routes of approach. Barrage to lift at Zero plus 5 minutes on to the line Spur-Puppy-Dog, which would then be the S.O.S. line if required.

The artillery available on the front of attack and in co-operation on the flanks consisted of 5 divisional artilleries, eighteen 6 inch howitzers, eight 60 pdrs., one 6 inch gun, one twelve and one fifteen inch howitzer, three 8 inch and three 9.2 inch howitzer batteries. It was organised into 4 groups, each of which synchronised several watches with Inf. Bde. H.Q., at 10 a.m. and 10 p.m. on June 13th.

Machine Guns.

Thirty-two Vickers guns assisted the Artillery with harassing fire during the preliminary phase. At Zero plus 1½ minutes (taking the signal from the artillery) fire was to be opened on the area between Bois de Vert and du Sart, Green and Lanyard. Twenty-four guns were employed on this task, firing *intense* (1 belt per gun per 2 minutes) until Zero plus 12 minutes, and then *slow* (1 b.p.g. per 15 minutes) until Zero plus 2 hours. Four guns were to move up after the attack into Hook.

Trench Mortars.

The Light T.M. Battery (3 inch Stokes) had 3 mortars registered for 'S.O.S.' work on the flanks of the attack.

R.E. and Pioneers.

One Section 529 (East Riding) Fd. Co. and 1 Company 20th K.R.R.C. (Pioneers) were allotted definite tasks to assist consolidation.

The R.E. were to convert a derelict trench from Tite's Copse to Long into a fire trench. The Pioneers were to dig two communication trenches from Hill to Hook in prolongation of existing saps. Both were to move up to their work on receipt of orders from Bde. H.Q.

Training.

It was obviously vital to have a good start. Various forms of signal were considered, but it was decided to rely upon practice with carefully synchronised watches.

As the attack was to be launched between 5 and 9 a.m. the assembly would have to be complete before dawn or the unusual movement in the trenches would attract attention. Low-flying aeroplanes were in the habit of coming over early every morning and the increased number of men might be noticed. An officer of the Divisional staff was sent up to report upon the effect of ordering the men in a trench to keep perfectly still and not to look up. Acting on his report arrangements were made to keep the men still and quiet,

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for them to crouch and not look up when aeroplanes came over, and for certain detailed men only to open rifle fire to give the impression that normal conditions prevailed.

Runner traffic was to be reduced to a minimum.

The attack was delivered by 2nd Bn. The Suffolk Regt. on the right and 1st Bn. The Gordon Highlanders on the left. Boundary between battalions—Green Lane. 8th Bn. The King's Own Royal Regt. and 10th Bn. The Royal Welch Fusiliers became involved shortly afterwards and took over part of the line.

BRIEF DIARY OF EVENTS.

June 2nd & 3rd. Practice ground chosen among old trenches near Arras, measured up and marked out from air-photos ; necessary filling-in, clearing and digging done during the night.

June 3rd. Battalions begin training.

June 6th. Battalions train separately on the practice ground.

June 7th. Reconnaissance by Officers and N.C.O's., final recognition of landmarks, determination of frontages and boundaries.

June 8th. First rehearsal by both battalions together.

June 9th. 9 a.m. Artillery programme begins.

June 12th. " Dress rehearsal," attended by G.O.C. 3rd Army.

12th-13th. Bde. takes over the Monchy sector. Enemy quiet.

June 13th. 7 p.m. Heavy shelling of Monchy.

June 14th. 2 a.m. Assembly reported complete.

5 a.m. Preliminary bombardment ends. Very quiet. Typical fine hazy summer morning.

7.20 a.m. Zero. Synchronization good.
The two battalions appeared from Hill as if by magic. Enemy in Hook completely surprised. A little bombing, then all quiet. Hook found to be only 3 feet deep and much damaged. Work of deepening and reversing parapet begun.

7.20½ a.m. One German field battery opened fire on Hill !

7.21½ a.m. Barrage. Enemy reply spasmodic at first.

7.25 a.m. Advance to Long and the Mound. Objectives quickly reached. About 90 prisoners taken. One Officer gave Boiry as the Reserve billets ; our 9.2 inch howitzers informed.

5.30 p.m. Brigade on the right reported much movement just south of Bois du Vert. Excellent work done by 60 pdrs. Enemy dispersed. Subsequently found to be an attack by 2 battalions ; no co-ordination, lost direction.

June 14th-15th. Some shelling.

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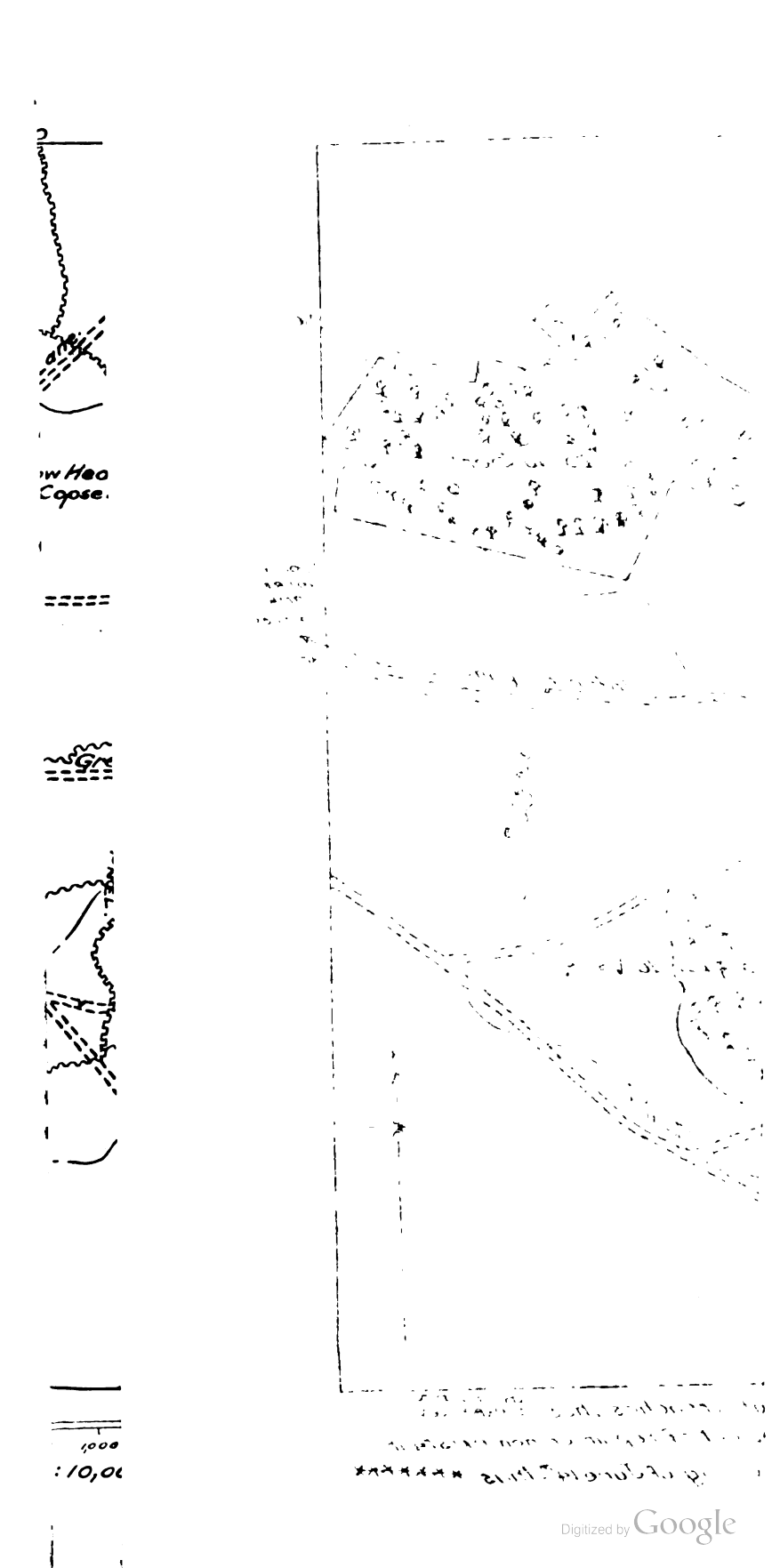

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June 16th. 1 a.m. Enemy opened "trommelfeuer" over the whole forward area.

2.15 a.m. Barrage on Hook and Long.

2.17 a.m. S.O.S. from the Mound. All the occupants of the 1st Gordon Highlanders' posts became casualties, and their shell-holes were occupied by the enemy. Enemy found to have employed 1 battalion.

10 a.m. Three unsuccessful bombing attacks made to recover one of the lost posts. A fourth made under a shower of rifle grenades succeeded.

June 17th. 1.45 a.m. Unsuccessful attempt to recapture the 2 lost posts. Enemy not surprised. Enemy aeroplanes very active all day, observing for the artillery. Balloon up in a new place. Suspicious.

June 18th. 1.15 a.m. Bombardment of our whole area and gas-shelling of battery positions.

1.20 a.m. "S.O.S." from the Mound. Enemy attacked and in places reached Hook. The garrison of Long was over-run but held out. At 5 a.m. the O.C. 2nd Suffolk Rgt. reported Long still in his hands, and the 529 Fd. Co. helping him to repair it. (This Company's casualties were 1 Officer and 11 o.r. killed, 1 Off. and 20 o.r. wounded).

This attack was found to have been made by some 1000 men of 3 different battalions. During the day the Trench mortars did excellent work, "putting up" enemy out of shell-holes to be dealt with by small-arm fire. Men's spirits raised accordingly.

10.15 p.m. All posts (except one obliterated) re-occupied with slight opposition.

June 19th-20th. Brigade relieved.

The total captures were 4 officers and 197 o.r. Prisoners spoke highly of our artillery and m.g. fire. One officer smiled when asked why they had no wire in front of Hook. He replied, "For the same reason that we have had no rations for three days."

Lessons learned :—None, unless the value of surprise is new.

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THE EXPERIMENTAL PONTOON EQUIPMENT.
(*Concluded*).

Contributed by the R.E. BOARD.

SUPERSTRUCTURE.

Meanwhile, assuming the distribution as far as calculable, figures were prepared and examined showing the strength required for varying numbers of joists for heavy and medium bridge, based upon an impact of 40 per cent. for lorries and fast traffic and 12½ per cent. for tractors and nil for tanks—also a safe working stress for a steel of 12 tons.

At the same time certain non-standard joists were considered which gave a saving of weight on a 9-in. x 4-in. mild steel joist (400-lbs.), *e.g.*, lattice joists weighing 270-lbs., pressed steel built up or fish bellied joists weighing 280-lbs. and finally 6-in. x 3-in. nickel chrome steel joists weighing 252 lbs.; the latter material entailed using seven joists for lorry bridge and 11 or 12 for heavy bridge, based upon 24 tons per square inch stress as against 12 for the others.

The use of nickel chrome steel had been under consideration for some time, but the provision of a small number of joists for trials had hitherto proved a serious obstacle, but eventually firms who were more encouraging were found and definite estimates obtained.

Meanwhile some rough tests of distribution of loads were made by laying joists over a bed of soft mud—the bearings being firmly supported. The results may be interesting in comparison to the assumed distribution.

The table appearing on next page shows the comparison between the assumed distribution of loads on joists and the distribution found by experiment.

As a result of these experiments it was decided to obtain 6-in. x 3-in. nickel chrome steel joists on the basis of five for light, seven for lorry, and eleven or twelve for heavy bridge.

To carry out more accurate tests for distribution of load a special gap was constructed which enables joists of any length from 15-ft. to 21-ft. to be tested. It is provided with a rigid structure under the joists for carrying instruments for measuring the deflection.

For the 21-ft. joists, which were expected to yield an ample deflection under live loads, no very accurate measurements were

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Loads.	No. of joists. 9" x 4"	Maximum percentage of ½ Total Load on any one joist. Assumed.	Found by Experiment.		
2T Axle Load.	5	100%	66.6%	Using 1½" chesses.	
			Decking.		
			Two 1½" Chesses.	3"	4"
3T Lorries.	6	90%	60.8%	62.4%	65.4%
	7	80%	62%	61.8%	60%
	8	70%	56%	52%	52%
	9	60%	56%	52%	52.4%
Tractor	8	40%	38%		
	10	33%	34.8%		
	12	30%	32.4%		
Tank.	8	40%	48%	.. Using 4" decking.	
	10	33%	37%		
	12	25%	32.6%		

necessary, and a simple device was provided in the form of a plunger graduated in fractions of an inch, provided with a self-registering cursor and held up against the underside of the joist by a stout elastic ring.

Seven joists (nickel-chrome steel) were spaced at 1-ft. 7-in. centre to centre and double chessed with service 1½-in. chesses Ribands of 6-in. x 4-in. were racked down by chains.

A loaded 3-ton lorry (5½-ton axle load) was used. Tests were carried out under the following conditions:—

(*a*) Lorry stationary and centrally with rear axle over centre of span.

(*b*) Lorry stationary with one wheel up against the riband and with its rear axle over centre of span.

(*c*) Lorry moving centrally at five to eight miles per hour. (The driver could not be persuaded to drive at this rate with his wheels close up against a riband).

The maximum deflection on any one joist (1.75-in.), which was obtained under (*c*), indicated a maximum stress of 13.3 tons per square inch, and an impact effect at 10 m.p.h. was deduced as 25 per cent.

An 8-ton axle load gave a deflection 2 9/16-in., which equals 18 tons per square inch, when passed over this bridge at 1 m.p.h. with one wheel against the riband.

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Corresponding tests for light bridge with five joists spaced 2-ft. 8½-in. centre to centre and single chessed, with ribands as before—loaded with a 2-ton pontoon wagon and four mules, maximum speed 8 m.p.h., gave a maximum percentage of load on one joist of 28.4, maximum deflection 1.09-in., stress 8.3 tons.

Other tests with different spacing of joists clearly demonstrated that the limiting factor was the strength of the chess and not that of the joists. Equally spaced joists were, therefore, adopted for light and lorry bridge.

It appears at first sight that the size of joists might be reduced, but owing to the whippiness of the 6-in. x 3-in. joist, such a course is not considered advisable.

The next problem was the saddle and the method of attachment of the roadbearer thereto.

The claw hitherto in use in the wooden roadbearer had various drawbacks, among others liability to bend and get in the way generally, and it was further anticipated that such a claw would be difficult to secure to a nickel chrome steel joist.

It was consequently decided to try the single pin now introduced. The obvious difficulty in its use was to find a means of securing it to avoid all risk of its coming adrift, particularly in view of the method adopted of ending the joist. This was achieved after various means had been tried and pins, secured by the present method, *i.e.*, welded into holes drilled in the joists, have been submitted to very severe trials without yielding.

The shape of the end of the joist had now to be dealt with. The alternatives of meeting butt-ended or overlapping had to be considered. A plain overlap was rejected for lack of space on the transom in heavy bridge for the 24 joists required, and for difficulty in racking down.

Butt-ending was clearly impossible owing to the gap in the roadway that would have to be left open to enable the pontoons to immerse without jamming the joists.

A halved end overlapping was, therefore, adopted after satisfactory evidence of a method of fixing the pin had been obtained.

Tests were made to detect any tendency of the joists to jam or to overturn. A 25-ton pontoon was floated by a 4-knot tide into a bridge without an upstream anchor. The bridge stood the shock without any disturbance.

It was found later that a tank, when making slight alterations in direction on a bridge, produced a distinct wobble in the roadbearers; this was rectified by the use of stiffening transoms, which are referred to later.

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The saddle presented no serious difficulties; when the decision as to the shape of the ends of the roadbearers and the method of fixing the same had been made, several patterns of saddle were made and tried out.

The question as to whether it was advisable to use a stiff saddle or one with relatively little strength against bending, was solved by a somewhat crude experiment. This experiment evolved ascertaining the stress in each case on the lower coupling.

Two pontoons, butted together, were supported on two rollers. The bottom coupling was replaced by pulley ropes which were rove crossways to holdfasts with a dynamometer interposed.

The pontoons were loaded with various weights. Two saddles were used—one continuous, made up of two steel channels 11-ft. long x 3-in. x 1½-in., the other of wood in two parts, each 5-ft. 6-in. long, butting over the line of contact of the two pontoons.

The lower corners of the pontoon were kept together by means of a winch, the tension on the ropes being measured by the dynamometer.

The strain due to a dead load of 7.9 tons, representing a lorry and superstructure, was 3 tons 6 cwt. for the stiff steel channel saddle and 3 tons 3 cwt. for the splitwood saddle.

This result bears out the theoretical conclusion that, so long as the rigidity of the saddle is less than that of the coupled pontoon, there is no relief to the couplings to be gained by the use of a stiff saddle.

The first pattern considered was wood, 6-in. x 4-in., with a top plate of ½-in. steel the edges of which were rounded, with slots to enable the joists, both in light and medium bridge, to be equally spaced. The length was 10-ft. 10½-in., enabling the ends to rest upon the cross frames of the pontoon in light bridge.

Under test this type of saddle was not found satisfactory as the wood did not provide sufficient resistance to the pins in the slots in case of any tendency of the joists to overturn. It was decided, therefore, to make the saddle of two channels on edge, resting on a wooden bedplate; between the channels steel castings, which contain the slots for the reception of pins, are bolted where required. This saddle also serves as a shore transom.

Under test these saddles have been found quite satisfactory. Owing to the heavy loads which come on to the pontoons in lorry and heavy bridge, it has been found necessary to reinforce with angle iron the wooden runners on the pontoon between which the saddle rests.

Having settled upon the saddle, the next problem was the racking down of the decking.

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To enable the same joists, ribands and racking to be used for single and double chessing, and also for the 3-in. decking recommended for the heavy bridge, involved considerable experimental work.

The rope lashings hitherto in use for racking are too quickly destroyed by the edge of the steel joist, and they cannot be made to develop sufficient holding power, so experiments were carried out on hooks, girder clips, wire rope and on chains, etc. Hooks, unless unduly heavy, deform to such an extent as to require very frequent tightening, and ultimately deform so much as to be useless—wire rope stretches too much and is also liable to fraying.

An early experiment with a ring bolt, fixed in a hole made for the purpose in the flange of a roadbearer, was thought to be effective, but subsequent tests in which a lorry was passed many times over a bridge showed that this was not so.

In fixing the roadway there are two problems involved—

(*a*) Preventing the chesses moving parallel to their length under the constant vibration; this necessitates buttons of some sort, either on the outer roadbearer or on the ribands.

(*b*) Preventing creeping of the whole roadway; this necessitates a very tight racking attachment.

It was found at first that the most effective way of preventing movement was by hook bolts pinned through the ribands, and fastening to special cast steel buttons rivetted to the outer roadbearers: or engaging in small projections rivetted to the outside of the joists.

Girder clips which slipped over the top flange were also tried and found to be effective.

It was considered, however, that the disadvantage thereby entailed, of providing two special roadbearers for each span was such that this idea was abandoned.

Various forms of chain and wire rackings were tried, both with screw and lever tightenings, and the pattern finally selected is a slight modification of the commercial "scaffixer."

Extended trials indicated that eight of these per bay were sufficient.

The original intention as to decking was to use single chessing for light bridge, double chessing for lorry bridge and 3-in. planks for heavy bridge.

The desirability of having one type of decking only has finally led to the introduction of the 3-in. plank for all three types of

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bridge; this plank is 9-in. wide and 11-ft. long, giving a roadway in the clear of 9-ft. 6-in.

The original ribands were 5-in. x 3-in. x 20-ft. 6-in. Oregon pine, reversible, provided with 1½-in. buttons on one side for use with single chessing in light bridge, and 2½-in. on the other for use with double chessing in lorry bridge. On the adoption of the 9-in. x 3-in. deal as decking for all types of bridge, the riband requires the 2½-in. buttons on one side only.

The design of the outside shore baulks, to enable the chesses (single, double and 3-in.) to be easily placed and secured, and at the same time to avoid loose parts, was not in the first instance met satisfactorily.

The present design has only one bolt, a fixed wing nut and a fixed (but pivoting) riband. It appears to meet the present situation (*i.e.*, light and lorry bridge) admirably.

The trials in lorry bridge of the equipment which has now been described, completed the first stage in the production of the new pontoon equipment.

The trials, to which this equipment was subjected, included, amongst others, the passage of a loaded 3-ton lorry 15,000 times over the bridge.

It now became necessary to consider the design of substructure for use in heavy bridge. (See Plate II.)

In heavy bridge, the piers consist of twin-coupled pontoons, *i.e.*, four pontoons in all. It became necessary, therefore, to design the short joists which would rest on the saddles of the coupled pontoons, and which would carry centrally the saddle for the long (roadway) joists.

Owing to the up and down motion of the piers under load, it was obvious that the short joists could not be directly below the long joists, otherwise they would foul.

It was decided, therefore, to try a compound joist made up of two lengths of 6-in. x 3-in. M.S. Another advantage of the compound joist was stability, which is not obtained with a single joist.

In order to retain the saddle, which takes the long (roadway) joists in a central position, angles were fixed to the compound joists. These compound joists are used also in the trestle tower.

It was now possible to form heavy bridge, for which 11 joists per bay are required. The decking used was 3-in. planks with the button riband as finally approved. Under load the compound joists were found quite satisfactory. (See Plate II.)

Experiments on dry land have shown that a tank, when changing direction, has a tendency to produce side wobble in the long joists.

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It was decided, therefore, to carry out tests with stiffeners.

The first idea was a diagonal stiffener of 3-in x 3-in. girder section, but this was not found satisfactory, owing to the long length of joist at each end unaffected by the diagonal.

Two stiffeners were then tried at right angles to the joists and spaced 7-ft. apart. Tests on dry land and in bridge proved that these stiffeners stopped all side wobble and also any tendency of the joists to overturn.

The stiffeners are fixed to the underside of the joists by fixed claws which grip the one flange of each of the 11 joists and by sliding claws which slide over the other flange; these sliding claws are then screwed up tight so that they do not move.

The whole operation of putting in a stiffener can be carried out by four men in 3½ minutes. Two stiffeners will be used in each bay of heavy bridge, and one stiffener in each bay of lorry bridge. (See Plate II.)

The pier of four pontoons (coupled and twinned) as used in the heavy bridge was not found sufficiently rigid; similarly a cut raft in lorry or heavy bridge requires bracing.

Trials have shown that two diagonal ties with tensioners are required in the pier for heavy bridge and for all rafts; in addition, pontoons must be lashed to one another bow to bow and stern to stern. (See Plate II.)

Only one length of diagonal tie will be issued, which will be sufficiently long for use under all circumstances; the adjustment to approximate length will be made by means of a bulldog clip.

In connection with rafts, further experiments have been carried out of forming cut.

The original experiments envisaged the use of derricks on a raft for raising the roadway of adjacent spans, but it was soon recognised that the raft would be very unwieldy in a swift current, and the idea was abandoned. It was decided then that forming cut must be made by means of rafts, which must be as small and as handy as possible. Rafts are, therefore, practically touching one another with a cut bay approximately 12-ft. long between rafts.

The cut bay consists of the same number of roadbearers as the remainder of the bridge, with the same type of roadway and ribands, etc. Cut can be made in 3½ minutes. (See Plate II.)

In order to carry the new pontoon, which is 3-in. wider than the existing pattern, the pontoon wagon will require alteration; or alternatively a new trailer must be designed.

The above completes the history of the development of the new pontoon equipment.

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It must be realised that the design of the components of this equipment grew up upon the following suppositions :—

(*a*) That the allotment of bridging equipment was to be approximately on the pre-war basis, *i.e.*, a certain definite allocation of transport to each division for floating bridge equipment.

(*b*) That with this transport the division should be in a position to provide the greatest possible length of bridge of the most useful nature.

(*c*) That the floating bridge, especially the light bridge, should be capable of construction in the minimum of time.

Various alternative proposals as to the relative quantity of boats, trestles, and superstructure that could be carried were considered, but since the bridging organisation has been changed these need not be referred to here.

The above equipment may not prove by any means the most suitable under all conditions, and investigations have been begun in the direction of a far more substantial type of floating bridge equipment.

CORRIGENDUM.

With reference to the last paragraph on page 303 of the *R.E. Journal* for June, 1925, the statement therein that consuta wood is unsuitable for seaplane construction is not correct. Consuta wood is used in the construction of seaplane hulls and floats.

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WATER SUPPLY FROM BORED WELLS.

By BREVET-MAJOR A. C. FINNIMORE, M.C., R.E.

SECTION I.—SUBTERRANEAN WATER SUPPLIES.

1. *Introduction.*

The art of well boring includes:—

(*a*) The selection of suitable sites for wells.

(*b*) The prediction of the depths at which water will be found and the quantity and quality of the supply that will be tapped.

(*c*) Estimation of the time that will be required, and of the degree of difficulty that may be encountered in the course of the operation.

(*d*) The selection of suitable plant and tools for the particular work in hand.

(*e*) The collection of the necessary plant, stores and personnel at the site, and arrangements for supervision, maintenance and repairs of the plant, and for the health and discipline of the crew.

(*d*) The performance of the work as arranged, and the surmounting of any unforeseen difficulties which may arise during the progress of the work.

It is intended in this article to outline the methods by means of which a Royal Engineer officer, who is not usually a specialist in the subject, may arrive at sufficiently accurate conclusions in selecting the site and method of boring for water, and some illustrations will be given of the difficulties which may be met during the practical execution of a scheme. Without the aid of a professional water diviner, a very fair estimate of the subterranean water supplies of a locality may be made by studying the physical geography of the neighbourhood.

2. *The Effect of Rainfall.*—It must be borne in mind that the water supplies of a country are dependent upon its rainfall, except for a small amount derived from heavy dews.

The total amount of precipitated moisture may be accounted for in three ways.

Heavy rains generally produce more water than can soak into the ground, and such precipitation results chiefly in the swelling of streams and rivers.

Light brief showers and dews do little more than moisten the surface of the ground, and most of the moisture so precipitated is either re-evaporated, or consumed by the vegetation.

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It is chiefly *gentle protracted rainfall* which soaks steadily into the ground, and fills the subterranean reservoirs. Water so soaking into the ground will continue to descend until it reaches soil which is already saturated, or until it comes to an impermeable layer, such as clay or rock. Few strata are absolutely impenetrable, and the depth of saturated soil above such a comparatively impermeable stratum will depend upon the relative rates of water supply from the surface, and of leakage, which may be downward or lateral.

3. *Underground Water Storage.*—If in any permeable layer the lower portion is saturated, and water is being added at one place, while in another leakage is occurring, then the saturation level will naturally be higher near the spot where the water is entering, and lower near the place at which the water is leaving the stratum. Between these spots the saturation line will fall gradually. This *hydraulic gradient* depends upon the rate of flow, and upon the resistance to flow offered by the material of the stratum.

A fault may sometimes cause a water-bearing stratum to be blocked, or more often a concave curvature of the strata may form a basin, and in either case a reservoir is produced, which will fill with water to some fairly definite level.

The tilting of the strata, and subsequent erosion of the surface, may expose a portion of a permeable layer at a relatively high altitude. A block at a considerable distance may then cause the whole stratum to become saturated, and the lower portions may form a subterranean store of water at great pressure, from which artesian supplies may be obtained at places where the ground surface is considerably below the level of the highest saturated portion of the stratum, which may be many miles away.

4. *The Saturation Level.*—Except for the small amount of water re-evaporated from the surface, the ultimate destination of all water which falls upon the land is the sea ; for any rise in the saturated level will cause an increase of flow towards lower regions.

Much water may find its way down in rivers ; but, nevertheless, if the rainfall of any country exceed the rate of re-evaporation, water will also flow underground towards the sea.

Unless the conformation of the strata is such as to lead the whole flow in some other direction, it may be assumed that in any country whose rainfall is considerable the saturation plane will never be lower than sea level, and that, in consequence, water will always be struck in a well sunk down to that depth.

Moreover, since the direction of flow must be towards the ocean, shallow pits, sunk within a few yards of the sea, will often fill up to sea level or a little above, not with salt water, but with fresh water that has been percolating seawards in the ground.

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Wells sunk further inland will generally fill to a higher level, due to the existence of the hydraulic gradient.

Thus water may be found at a considerable height above sea level, even where there are no impermeable layers to hold it up, but only the resistance to flow offered by relatively permeable or merely fissured strata. It should be realised that some strata such as sand or gravel may be truly permeable; while others, such as chalk, which are not really permeable in themselves, may nevertheless contain a considerable quantity of water, and may provide a copious flow, not in the pores of the material, but in crevices and fissures, which abound in chalk formations.

SECTION II.—WELLS.

1. *Surface Wells.*—Wells sunk only a little below the saturation line, though they may provide an ample supply of water, are neither reliable in quantity or quality. In dry weather they may fail, and normally a large amount of water contaminated by sewage may enter them before it has been effectively filtered.

Such wells are generally dug and lined with brickwork steyning. If the steyning is well built and properly capped to keep out the drainage water at the surface, they may be comparatively safe, but only if they are of considerable depth.

2. *Deep Wells.*—Wells sunk beyond the first impermeable stratum into the water-bearing strata below are in every way preferable to shallow wells. The stores of water are less affected by dry seasons, and the purity is generally assured, provided the steyning is well sealed into the impermeable layer through which it passes.

Such wells, if dug and lined with brickwork, are expensive and slow to produce, but have the advantage that large pumping machinery can be installed.

3. *Chalk Wells.*—In chalk and limestone districts, although the general rule regarding saturation line and hydraulic gradient still applies in principle, the problem of finding adequate supplies of water is complicated by the fact that the substance is only slightly porous, except for fissures, which provide passages through which the water can flow. If a well is dug down to the saturation line, water may appear, but will only enter very slowly unless one of the larger fissures is met. In that case also the delivery will be limited to the quantity of water carried away by that particular fissure.

To increase the quantity of water obtainable, it is necessary to drive out galleries below the saturation line, so as to intersect other fissures. The water obtained is generally bacteriologically pure, but is nearly always very hard. To obtain soft water, it is necessary to drive down right through the chalk and the clay that normally

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lies under it, into the permeable layers below, which are generally sandy, carefully sealing out the chalk water.

For ordinary water supply purposes, it is usual to mix the chalk water with a proportion of the artesian, or sub-artesian, water from below, sufficient to render the hardness less objectionable.

4. *Boreholes.*—A much less expensive method of tapping the supplies of water at low levels is to bore a hole of only a few inches diameter, by one of several methods of drilling. The work can be done expeditiously, and supplies sufficient for many purposes can be obtained from a small borehole.

Where the water is truly artesian, that is, when the subterranean pressure is sufficient to drive the water out of the top of the hole, the method is simple and as near ideal as can be found.

It is seldom that truly artesian supplies are found, but frequently the pressure is sufficient to drive the water fairly near to the surface. Boreholes suffer from the disadvantage that only small-bore pumps can be used; and since the weight of the rods of a deepwell pump absolutely prohibits anything approaching high speed working, the delivery of water is small.

In consequence it is normal to sink the well down to some fifty feet below the hydraulic level, of a diameter sufficient to accommodate a suitably large pump, and thence to continue down to the water-bearing strata at a reduced diameter.

For the supply of towns requiring millions of gallons per diem, it is usual to sink a dug well to accommodate the pumps. The borehole to obtain the sub-artesian water may then be driven from the bottom of this well; or it may be driven alongside, if preferred, and the water carried into the pump-well through an adit, placed well below the hydraulic level of the water. The latter method is preferable, since the borehole can then be deepened or cleared out without dismantling the pumps, and conversely the pumps can be isolated entirely from the borehole by a valve in the adit, and the pump-well emptied, if the pumps should require inspection or repair. This method also provides for mixing different waters.

5. *Air-lift Pumping.*—For military purposes, which often necessitate quick installation, the mechanical efficiency being unimportant, the air-lift method of raising water is very suitable. The borehole need then be only of sufficient size to accommodate a rising main which will carry up the required quantity of water, since no pump is required in the well. A compressor at the surface is made to drive compressed air down a small pipe carried well below the surface of the water. The air is liberated in small bubbles into the water, whose specific gravity is thereby greatly decreased. A subterranean pressure, which can only force pure water about half way up the tube, will force the aerated and lightened water right up to the surface and deliver it in large quantity into a tank.

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SECTION III.—METHODS OF BORING.

1. *The Norton Tube Well.*—A method of reaching water supplies that are at a slight depth only, and to attain which it is not necessary to traverse any hard strata, is provided by the Norton Tube Well. This consists of a stout pipe in sections, the lowest of which has a conical point, and is pierced with many small holes through which water is expected to enter. It is driven as a pile to the required depth.

Such wells have in any case a small delivery, they cannot be driven to any great depth, and cannot pierce any strata much harder than loams, sands and clays. The grid is easily blocked, and although it can generally be cleared by forcing water down through the tube, the inconvenience is considerable.

2. *The Earth Augur.*—A method available for sinking an open ended pipe in soft ground is that of removing the soil at the bottom of the pipe by means of an augur in the form of a shell, containing screw blades, and then driving down the pipe into the hole, which is necessarily of less diameter than the pipe.

The method is expeditious for shallow borings, but becomes very slow and tedious at greater depths. It cannot be applied to hard strata, such as chalk or rock of any description.

The augur is fixed to the end of a line of screwed rods, all of which must be drawn up every time the augur is filled. Progress becomes slower and the labour heavier as the depth increases, and with it the number of rods to be fixed and subsequently withdrawn at each filling. The method is chiefly used in clay soils in which there are no stones to prevent the use of the somewhat blunt and fragile augur.

3. *Rotary Drills.*—The rotary or trepanning drill is a development of the augur.

Within a tube lining, which can be sunk at first by means of an augur until the first hard strata are encountered, a separate boring tube is placed, fitted with means for revolving it, preferably by power such as a steam engine.

The lower end of the tube carries a trepanning tool, consisting of a special section of tube carrying a number of cutting teeth. As the trepanning tube revolves, the teeth cut an annular groove, leaving a solid core which enters the tube. At suitable intervals the tool is drawn up and the core removed.

In comparatively soft rocks hardened steel teeth are capable of cutting satisfactorily, and by substituting, for the steel teeth, diamonds set in suitable sockets, the hardest rocks can be cut; but progress is necessarily slow. Conversely, when boring in clay, the teeth are not necessary, and a plain pipe will descend if rotated with sufficient weight upon it, or even if dropped repeatedly upon

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the bottom. Rotary drills present the peculiarity, most valuable from a geological point of view, that the core is removed undisturbed, with all the strata clearly defined and capable of accurate measurement, examination and analysis.

Whereas in soft ground the tool can be followed by a lining tube of slightly larger dimensions, which can be driven down around it, when hard strata are being penetrated, the tool can only cut a hole of its own diameter. If further soft strata requiring lining are found below, it is necessary to continue with a smaller lining and tool to correspond.

4. *Percussion Drilling.*—A rapid method of sinking an open ended tube consists merely of pulverising the ground immediately beyond the foot of the tube by repeated blows from a chisel, which may be handled by means of a rigid line of screwed rods or pipes, or merely by means of a rope.

The normal method of removing the soil is to churn it up with a quantity of water, which may have to be introduced for the purpose, and then bale out the resulting gruel with a tubular bailer or bucket, the bottom of which is generally fitted with a valve to facilitate the entry of the semi-liquid contents of the hole.

The form of chisel used depends largely upon the nature of the strata to be pierced, and also to some extent upon the method of working. The main requirements are, firstly a transverse edge that will break up the material directly opposed to the tool, and secondly a circular edge, which need not be continuous, to form the hole, leaving it round and clear.

In application, the chisel must be rotated slightly between successive blows, so that the edges may meet fresh material at every blow.

The angles of the cutting edges must be suited to the strata. In very hard material an obtuse edge is required for strength, since an acute edge would quickly break up, and correct hardening and tempering are of great importance.

In soft strata the angle and temper of the edge are of less importance, but here the quicker penetration of an acute edge is valuable, and such an edge is not so likely to break up.

The method of drilling with rigid rods is slow, and very laborious at great depths; since every length of rod must be unscrewed in turn, as the tool is raised after a period of drilling, before the bailer can be used, and they must again be screwed together, as the tool is lowered again. The method is preferred by many to the rope system, on account of the greater freedom from accident due to breakage. The speed of progress can be increased while traversing soft strata, by substituting a shell tool, consisting of a length of tube with a cutting edge and an internal throat near the foot, which collects the spoil inside it, and brings it up as a core when raised. Shells are particularly effective in strata consisting largely of clay.

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5. *Rope Drilling.*—A very ancient method of sinking tube wells, which has been much used in the oil-fields of America, consists of suspending a heavy "string" of tools to the end of a rope, which is normally passed over a sheave at the head of a derrick, and brought down to a winch, which is generally power driven. This principle is often applied when rigid rods are used in the well, the rope being fastened to an eye on the uppermost section of the rod, which is always above ground level. In the American system a short metal rod is used, of a length only sufficient to guide the tool straight; the rope is taken down the well, and may be several hundred feet long, or even thousands. The elasticity of the long rope is considerable; and advantage is taken of this elasticity to economise in power, by storing energy in the tool, on the principle of resonance. Some device is provided for plucking, or shortening up the rope by two or three feet, and then releasing it. This "spudding" device should be tuned approximately to the natural frequency of the vibrations of the tool with the length of rope in use; then the vibrations will increase until the stroke of the tool may be twelve or fifteen feet.

The length of rope should be adjusted by means of the winch, so that the tool may strike the bottom vigorously, but not as a dead blow. The blow should be sharp and elastic, with the rope tense at the time, so that there may be no dwell at the bottom. Thus there is less tendency for the tool to stick, and a saving is made in power expended in retracting it, the heavy pull often needed in soft ground being supplied by the tension in the rope.

This method of drilling is very rapid, since the frequency of the blows is high; and after drilling for a suitable period, when the accumulation of debris makes it necessary to clear the hole, the tool can be very quickly hoisted by the power winch, so that the bailer can be used. There is an element of risk in the uncertainty of the life of the rope; and the breakage of a rope may lead to the loss of a string of tools in the well, which may have to be abandoned and a fresh bore started.

Apparatus is now available for fishing for a dropped tool, which if skilfully and energetically applied at once, before the tool can be buried by the debris washed up by inflowing water or falling from the sides of an incompletely lined hole, will generally recover the tool without much delay.

During the 1914-1919 war, boreholes of 200 to 400 ft. depth were normally drilled by this means in one week of continuous work, night and day, two crews working in reliefs of twelve hours each, and the strata to be penetrated being generally chalk or clay, very easy strata. At least a month must be allowed for such a bore, made in normal circumstances, working eight hours a day. Naturally, the existence of hard strata greatly increases the time required;

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for whereas a day of twenty-four hours' work may produce an advance of one hundred feet in chalk or clay, only three feet of a hard rock may be pierced during the ensuing day. Therefore, estimates of time required depend upon geological information.

Section IV. Plant for Percussion Drilling (Rope System).

Illustrated in *Military Engineering*, Vol. VI. Water Supply.

1. *The Boring Bit or Chisel.*—The bit is normally a fluted shaft of mild steel about four feet long, to the foot of which is welded a short piece of tool steel of a moderately high carbon content, sufficient to take a good degree of hardening without being too difficult to work.

This hard point requires to be so forged as to comply with the essentials outlined in Section III, paragraph 4. The angle of the actual chisel edge will depend upon the hardness or softness of the strata to be pierced. An included angle of 45° may be satisfactory in clay containing no large stones, while chalk, especially if it contains much flint, requires a stronger edge, such as 90°. In rock, the included angle may be from 120° to 150°, according to the hardness of the strata.

The circular edge, which shapes the hole, is not carried right round the circumference; but is normally limited to two portions of about one sixth of the circumference at opposite points. The remainder of the circumference is forged down to continue the flutes in the shaft, which permit the debris or drillings to escape away from the point. This forming edge is generally forged to a right angle. It should be a true edge or "arrise," and its bite is very important; for a blunt forming edge will allow the hole to become tapered and jam the drill; while a good sharp edge here will cause the chisel to cut large, and so keep itself free in the hole.

2. *Forging and Tempering Bits.*—The bit should be frequently re-forged. It will not remain sharp long in soft ground; and when drilling through rock or flinty chalk, it should not be used for more than a very few feet of descent without re-forging.

It must be brought accurately to size by setting up the point. A gauge of precisely the diameter of the tube lining should be used. Since the bit is gauged while hot, it will run easily in the tube when cold, for it will shrink considerably.

The point should be heated cherry red, and slaked out in brine, using a shallow-tub, in the bottom of which a piece of iron or steel plate has been laid to protect the wood. The temper should then be allowed to run down till the whole of the forming edge has just turned blue, and then finally quenched out.

3. *Taper Threads.*—The screwed connection between the "Bit" and the "Stem," the main shaft of the string of tools which supplies

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the weight and direction, is normally of a steep taper. Thus the root of the "Pin," or male screwed portion, is strong. Similarly the "Box," or female portion, can be relatively thin at the exterior edge, while the walls are strong at the base.

The steep taper is a convenience in handling the string of tools when assembling or taking apart; since only a few turns are necessary, an important matter, for every part weighs several hundredweight. On the other hand, any slackness in tapered threads will lead to the string coming adrift while drilling. It is, therefore, essential that the threads shall be carefully protected from burring, by keeping them protected at all times by caps and plugs when not assembled in the string. They must be preserved from rust by ample coatings of grease; and before assembling them they must be absolutely clean and bright, since the slightest trace of grit will prevent them from screwing home properly. The direct thrust of the blow is not taken by the threads, but by accurately machined faces on the external portion of pin and box. These faces must be similarly protected and cleaned.

4. *The Boring Rig.*—The essentials of a boring rig are:—

(*a*) A derrick high enough to suspend the string of tools completely clear of the borehole, allowing for some projection of the tube lining, and strong enough to carry not merely the deadweight of the tools, but their live weight when working, and also the very heavy pull needed to dislodge them if they should stick. One large sheave is required for the drilling rope, and a smaller one for the "sand-line," a light wire rope used for handling the bailer and other light articles.

(*b*) Drums or winches to hold the drilling rope and sand-line respectively.

(*c*) A prime mover, generally a steam boiler and engine, capable of being put in gear with either winch separately.

(*d*) At least one means of working the tool by short pulls on the rope, and preferably two devices. One, for working on the portion of rope descending from the derrick head to the drum for starting the borehole, is known generally as the "spudding gear," and generally operates by plucking the rope by sudden movements of a jockey pulley. The other, for working on the rope close to the well head when the tools are below ground, is generally known as a "walking beam," and its object is to simplify the action and save the wear on the rope that occurs when working over the derrick sheave.

For convenience, either rope drum and either drilling gear should be capable of being put in gear with the engine, separately or in conjunction as desired, by means of separate controls. The main rope drum should have two separate brakes, and the sand-line one.

Friction drive is usual for both drums, except in heavy oil rigs for depths exceeding 1000 feet. It has the advantage that the engine

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can be kept running all the time, and the drive is taken up without shock. All this gear, including the prime mover, is normally mounted on the same chassis, in the portable form that is most suitable for service purposes. It is also a great convenience if the engine can also be put in gear with the road-wheels, for shifting the plant over the hole and away as desired. The machine should not be expected to travel long distances under its own power, but should be carried by rail as near as possible to its work, or towed by traction engine if no rail is available.

The normal type of construction for chassis and derrick is the composite, struts and beams being of timber, and ties of steel rod. This is an advantage in isolated situations, since all repairs can be carried out by a wheelwright, or by a carpenter and a blacksmith. A small forge and anvil are normally provided with the rig, and a steam operated blower, for the main purpose of reforging blunted tools.

A self-propelling plant requires a platform, carrying a small coal box and water tank, and steering gear. For convenience in transport the derrick, chimney, and travelling platform should be capable of being removed with ease, and it is important that the overall dimensions shall be within the loading gauge of the railways to be used in getting to the site when such removable parts are taken on. A low truck is in any case necessary; and this entails some delay in arranging a move unless ample warning is given to the railway operating authorities.

5. *The String of Tools.*—For convenience in handling and working, the various portions of the string of tools are all screwed together with taper screws, and easily detachable. The bit screws into the foot of a stem, usually about 18 feet long. The stem screws into the rope socket, into which the rope is passed, and generally held in place by splicing back the rope into a cone shaped head to fit a corresponding conical hole in the socket.

When once the tools begin to disappear into the borehole, it becomes necessary to provide some means of delivering an upward blow to dislodge them if they should stick. For this purpose a pair of jars is placed between the stem and the rope socket. The jars consist merely of two links of chain, enabling an upward blow to be given by slacking off the rope until the links open, and then using the socket and upper link as a hammer by pulling up the rope.

At any time the string of tools can be unscrewed at any joint for some other tool to be substituted. For instance, a hook, screwed to fit into the rope socket, can be used for lifting tubes or any other weight by means of the derrick and winding drum; or a shell may be substituted for the chisel below the stem.

6. *The Temper Screw.*—After the borehole has been driven to a depth of one to two hundred feet, it is better to use the walking

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beam instead of the spudding gear and derrick, although it is still possible to spud down to about four hundred feet. Spudding is the quicker method, but causes more wear. The temper screw is coupled to the yoke of the walking beam, and clamped to the rope at its lower end. While working, the screw is revolved a little between each stroke, and so the tool is kept rotating to make it cut freely, and simultaneously lowered as required as the hole deepens.

7. *The Floorjack and Spanner.*—The pressure exerted upon the chisel by the inertia of the other tools above it when it strikes rock, is enormous. This pressure is taken by the faces surrounding the screwed portions of the joint. If these faces can be forced closer together, the threads are thereby loosened, and may come unscrewed, particularly if the tools are spinning when the chisel strikes.

The only way to prevent this possibility is to cause a greater initial stress on the faces than the blow will cause. Then the opposing pressure of the threads will never be quite removed. Very powerful spanners are therefore provided, and a "floor-jack" with which a pressure of some twenty tons can be applied at the end of the spanners. The tools should be screwed up until two men swinging on a 6ft. handspike can drive the jack no further. The threads must be loosened when required similarly by the use of the jack. On no account should any attempt be made to loosen them by using a hammer in any way, since the jar may cause the threads to seize. If seizure occurs, the threads will be destroyed completely. The old-fashioned method of heating threads to loosen them may also be fatal in this case, since the pressure is great enough to cause welding at a comparatively low temperature.

8. *Tubes for Lining Boreholes.*—Three types of tube are used for lining bored wells, the choice between them depending mainly upon the strata pierced and the depth of well. In firm strata, in which the tool cuts a fair hole only a little larger than itself, or for comparatively shallow wells where little force will be needed in any case for driving, it is usual to line with Flush Jointed Casing tube. This is a weak lining, since the thickness is reduced by the screw threading to about one third at the joint. It generally sinks without any driving and is easy to withdraw.

In softer strata which are liable to collapse against the pipe, and make driving necessary, it is necessary to use something stronger, and for this the Swelled Casing may be suitable. It is fairly strong, but requires considerable driving, and is heavy to withdraw, on account of the friction of the joints in those strata which press on the casing.

In strata which bring heavy pressure upon the pipe, and therefore necessitate heavy driving to force the casing down, Butt Jointed Drive pipe may be necessary. This is very strong, and will stand much heavier driving than swelled pipe, but offers more resistance

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both while it is being driven and if it should be desired to withdraw it. The bottom of the casing or pipe should be protected by a driving shoe of tempered steel, larger than the casing, or larger than the couplings if drive pipe is to follow it. This shoe should have a strong cutting edge of an angle of about 80°, and must be very well jointed to the pipe.

The pipe may be driven by means of driving clamps which, when bolted together on a squared portion of the string of tools, constitute the latter into a pile—driving monkey of great driving power. The head of the pipe requires a protecting cap or driving head. This should fit inside an externally threaded pipe, or outside an internally threaded socket; so that the threads may not be damaged. Pipe lifting clamps are generally made to lock round the pipe by means of a drop line, and have strong lifting ears or links. A socket or coupling should be screwed on above the clamps or they may slip. In conjunction with these clamps a pipe lifting hook may be used in the rope socket. A more powerful lift is obtainable by hooking in a large snatch-block to the lifting clamps, passing the rope from the derrick through the block and up again to an eye placed fairly low down on the derrick, thus giving a double purchase.

9. *Fishing Tools.*—Well boring is fairly simple straightforward work, provided sufficient care is exercised that nothing goes amiss. Accidents may occur, or errors may be made by the operators, producing any one, or any combination of the following stoppages.

(*a*) The tools stick, and cannot be withdrawn by the winch.
(*b*) The rope breaks in the well.
(*c*) The pipe caves in or breaks.
(*d*) The tools come unscrewed in the well.

When any one of these accidents occurs, and the tools are down the well, it is imperative to act at once with energy, since the chances of raising them again are in inverse proportion to the length of time they are down; and all the time dirt is settling down alongside and over them, or being washed up from below, jamming them worse, and finally burying them.

Fishing tools include a spudder for clearing the hole round lost tools, rope spears for catching hold of a broken rope, knife and chopper for cutting away the rope if a spear cannot get a good enough hold, and various sockets and latches for getting a grip of the lost tools when the rope is cleared out of the way. There are also swages for re-forming collapsed casing, internal pipe cutters, and a bumper for driving down a string of tools that may have stuck while hoisting them, owing to either casing bulging in or to a stone lodging alongside the tools.

A set of fishing tools should be strung together without delay, consisting of rope socket, sinker or short stem about 12 feet long, a pair of long stroke or fishing jars, and the suitable tool.

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Unscrewed tools may be recovered by dropping one of the various sockets available over them.

Stuck tools may sometimes be freed by jarring upwards, but the fishing jars on the rope may break.

The rope spear will generally take hold of a broken rope, but will only tear out if the tools are badly stuck. In this case the rope must be completely chopped up and fished out, leaving the hole clear for the use of a string of fishing tools upon the lost set.

If the jars break, the appearance of the portion left on the rope socket will indicate the shape of the portion left below, and a suitable latch or socket must be put on to the fishing string.

If a good hold is obtained, and the only result is another broken rope or jars, it is unlikely that the tools will ever be recovered, and further attempts will probably be a mere waste of time and expense.

For military purposes when time is of more importance than anything else, it is essential that several spare sets of drilling tools should be available, so that if one is lost, a fresh borehole can be started at once. The heavy expense of maintaining any unit on active service, and the importance of employing all non-divisional troops on directly useful work only, will necessitate abandoning lost tools unless they can be very easily recovered, at any rate temporarily. In a slack period it may be possible and profitable to return and continue fishing operations, but only if the boring section would otherwise be idle.

SECTION V.—PRACTICAL DIFFICULTIES.

1. *Introduction.*—In the practical work of a well-boring section, locomotion is at present one of the greatest difficulties. Lack of correct geological information is another; and insufficiency or unsuitability of the tools provided may be equally disastrous.

A brief account of the problems encountered during the past year by the two crews based on Chatham may be of interest in showing the type of difficulty that may be met.

2. *Borehole at Digby, Lincolnshire.*—On the first of May, 1924, a Keystone Drilling Rig of the type described in *M.M.E.*, Vol. VI, was sent from Chatham by road to Digby, in Lincolnshire, towed by a traction engine, with a crew of one sergeant and three sappers.

The journey was disastrous, since the Keystone machine could not stand the strain of travelling on a hard road at traction—engine speed.

On the 3rd May, after travelling 62 miles, a casting, which held the back axle, broke in two. The next day was spent mainly in wedging up the back axle with hardwood blocks, after which 7 miles were covered. It was observed that several stays holding the boiler to the chassis had broken, that many bolts were missing, and the machine was suffering generally from the effects of jolting.

The remaining 78 miles were covered in the next two days, but

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the machine was almost in pieces. The repairs necessary before it could be used occupied ten days, and on May 17th work was commenced. By the end of the 20th, two feet of Pinnet gravel and 6 feet of Hard Silicious sandstone had been pierced, when a valve rod on the engine broke, probably in consequence of the road journey. The repair occupied two days, during which the opportunity was taken to rig up a blacksmith's hearth for dressing tools, and to dig some drainage pits.

On the 23rd two feet of progress was made in the sandstone, but the 24th was spent in dressing up the now badly worn bit. By the 31st the depth of the hole was 47 feet, the last 2 ft. 6 in. being in hard blue stone, very difficult to drill.

On the 2nd of June, the 10 inch bit came unscrewed, and was fished out, no progress being made.

On the 12th of June, at a depth of 80 feet, water was rising in the bore. Much trouble had been caused by pieces of the hard stone dropping alongside the tools and jamming them.

Progress was now very slow, during one day no measurable progress was made, and by the 1st July the depth of the bore had only reached 105 feet. Some trouble had been caused by defects in the boiler injector and feed pump, and one day had been spent in recovering the bailer which had stuck.

On July 2nd, sand seemed to be rising in the borehole, and further progress was thought to be impossible without lining the hole with tube, so as to guide the tools through the sandbed which had apparently been reached. Tubing had been ordered before the crew started, but owing to various troubles, suitable tubes did not reach the site till September 14th. A temporary piece of pipe about 12 feet long had been used to hold up the surface soil, and when the proper lining arrived it was found that this short length of pipe could not be withdrawn. By September 22nd it had been removed, using hydraulic jacks and specially made clamps; but now the new tubes would not go down the hole, since they were slightly oversize. The 10 inch bit was set up to a larger diameter, and by September 30th it was ready for work again, as shown in Fig. 1.

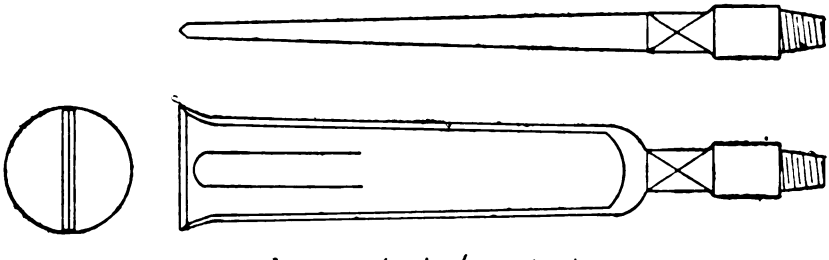

FIG. 1.

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The reboring was completed on October 20th. It was found very difficult to keep the hole to gauge, and when the tubes were put down, they refused to descend further than 21 feet. It was now evident that the tool used had been too narrow, and had not sufficient circular cutting edge to make a round hole. It had not been turning, and had merely cut some featherways, as illustrated in fig. 2.

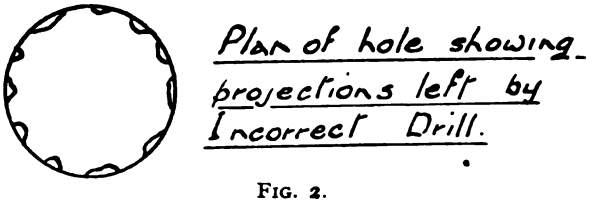

FIG. 2.

This featherway cutting is always likely to occur when re-boring unless a tool with very wide circular cutting edges is used, such as that shown in Fig. 3. By 29th October such a tool had been ob-

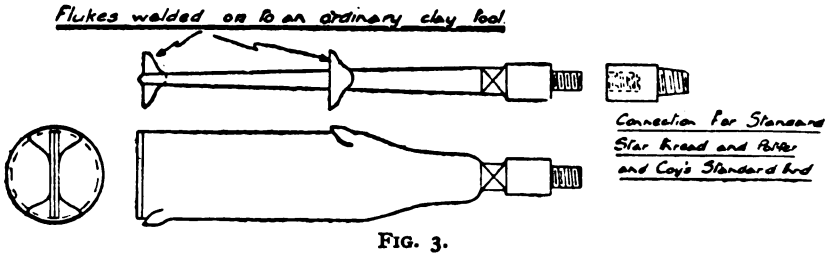

FIG. 3.

tained, and on November 22nd the hole had been properly rebored to 78ft. 6 in. This tool had stuck frequently, and the cable had broken several times. The welds between the ring and the tool had also opened out considerably. Now the tool stuck badly, and in trying to dislodge it the derrick of the rig was broken. Fortunately no one was hurt, but the derrick required to be completely rebuilt, and was only ready again on December 10th.

By January 6th, 1925, the hole had been drilled to 120 feet, the full depth intended.

The suspected bed of sand did not exist. The section of the well is shown in Fig. 6.

At 115 feet, subartesian water was struck, and the level rose in the bore to within 27 feet of the surface. On January 8th tubes were put down to 29 feet, where they stuck. They were withdrawn and $\frac{1}{8}$ inch diameter skimmed off the cutting shoe. They then descended to 36 feet only. Finally they were driven to 54 feet, and grouted in with cement.

The job was finished on January 28th after 8 months' work, much too long, but the work had been done three times over, and much time had been spent in effecting repairs or waiting for stores. The actual days spent in boring were not excessive, and everyone had

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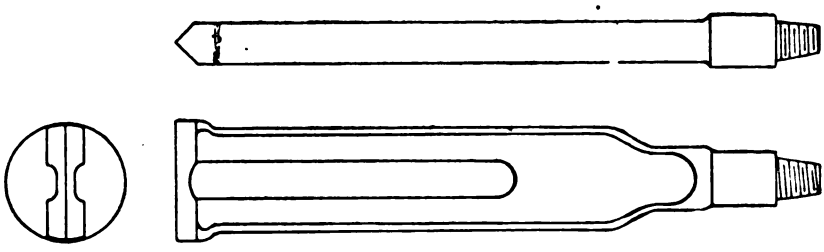
gained experience in working under different circumstances and in totally different strata to the chalk and clay at Chatham.

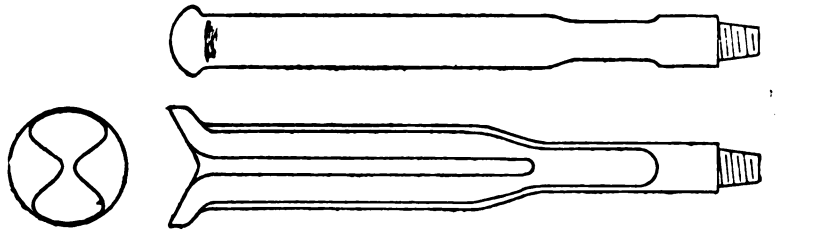
The difficulties in boring were mainly due to using unsuitable tools. Fig. 4 is a proper rock bit, but the tool used first was as Fig. 1.



— Correct Rock Drill —

FIG. 4.

The improvised reamer shewn in Fig. 3 was weak ; and it was only when one as in Fig. 5 was obtained that progress was satisfactory in the re-boring operations.



— Fluked tool. Used for enlarging Borehole by Reboring. —

FIG. 5.

3. *Boreholes near Puddletown, Dorset.*

The Star Drill left Chatham on May 20th for Puddletown, near Dorchester, with a crew of one acting lance-corporal (trained in well boring) and three sappers under instruction.

In spite of orders that the speed was never to exceed 4 miles per hour, a front wheel came off the drill the first day, and the road was completely blocked for an hour.

The second day, going from Westerham to Dorking, 7 spokes broke in one hind wheel and one in the other, while the front wheels frequently overheated and required removing for lubrication.

On the third day, four miles from Aldershot, one hind wheel collapsed, and the Star drill was abandoned. Next day it was got clear of the road, and the back axle was taken off to be taken to Aldershot. By the 28th two traction engine wheels had been fitted and the journey was resumed. Now the machine had no brakes. On the 31st May the drill and crew arrived at Puddletown, but the

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repairs necessitated by the jolting on the road occupied fifteen days. Various palm stays in the boiler had worked their rivets loose, and formed oval holes in the boiler shell. The steam pipe was broken, and a derrick stay had pulled out from the boiler. Apart from this, the damage done to the roads had upset the equilibrium of many ratepayers.

The boring of the first well was an easy proposition, since the chalk strata were familiar to the crew. The well was down 220 feet in eight days, and water stood at 49 feet from the surface. The machine was then moved half a mile to Waterston, and the second well commenced. Here the circumstances were very different. The bore was sited in the broad bed of a meandering chalk stream, only a hundred yards or so from the river itself. Any engineer conversant with well boring could have predicted trouble, but there was none on the spot. The difficulty in such a position lies in the fact that there is usually a heavy underground flow below the visible stream in chalk; and in consequence the bed is principally formed by subsidence, the chalk being thereby disintegrated for some distance below the surface. In two days twenty-four feet had been drilled, and then for nine days no progress was made. The bailer would not reach the bottom of the hole. The tools were working in a wet mass of sediment and broken flints, and brought up the tube with them at every up stroke. Quantities of stuff baled out were replaced continually in the hole by subsidence in the surrounding ground, and a cavern had formed round the tube as represented in Fig. 7. To save the drilling machine from being engulfed it was shifted away and a new hole started in slightly firmer ground on July 11th. By the 16th it was 50 feet deep, and the water stood at 6 feet below the surface.

SECTION VI.—CONCLUSIONS.

1. *The Machine.*—It will be seen that when time is an important factor the transfer of the plant to the site is as important a consideration as the operation of boring. In one case a journey of 6 days caused damage which required 9 days to repair. In the other 12 days were occupied in covering 160 miles, and 15 days were then wasted in repairing the plant.

The American machines now used are quite unfit to travel long distances; a much better type of chassis should be provided, with tyres that can be trusted to cause the minimum of damage to the roads. Giant pneumatic tyres, with a well sprung chassis, would probably eliminate all this trouble.

2. *The Crew.*—During the war of 1914-18, two machines were used at one bore, each machine by its own crew, working in reliefs. Every crew consisted of a foreman, well borers, smiths, fitters, engine driver, cook, etc. When a crew turned in after working a relief, the

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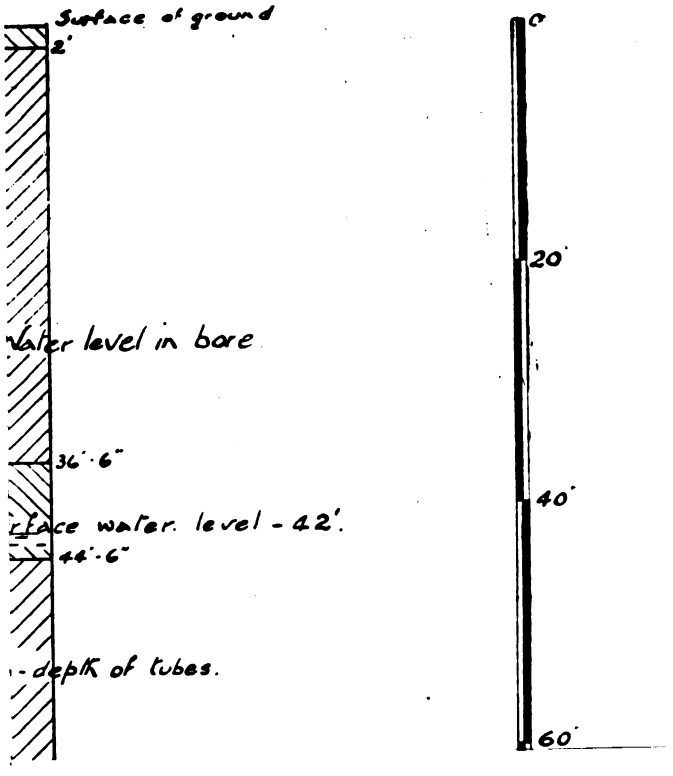
OM BORED WELLS.



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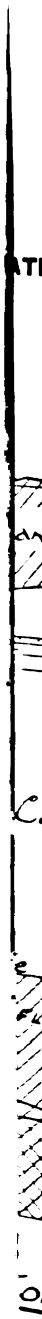

n relief
ry crew consisted of a foreman, well borers, smiths, fitters, engin
er, cook, etc. When a crew turned in after working a relief, th

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machine was run back away from the hole, the fitters went over the machine and effected any repairs needed, the smiths dressed the chisels, and the cook fed the crew. In consequence no time was lost, and no one was kept waiting. It is very poor economy to work with an insufficient crew. for in that case any repair to the machine, the dressing of a bit, or a trip to a neighbouring town for supplies or stores, will mean a day lost, because the well-borers must do these odd jobs.

3. *Supervision.*—It was very obvious in the cases quoted that the crews suffered from being "nobody's children." Difficulties arose over billeting, rationing and discipline. Important stores were delayed. Information was often lacking as to progress or difficulties encountered; and much time was lost from a lack of co-ordination. The inference seems to be that one officer should give his whole time to the supervision on one boring operation. He should be not merely trained in the operation, but also well provided with geological information.

He should be given ample warning of all schemes, so that he may have time to visit the site, decide on his plan of action, and demand the necessary stores in time to ensure their arrival before they are required. He should also have a reasonably free hand as regards the operation itself, and freedom to act on his own initiative. in case of any breakdown, for a delay may be more expensive than a repair of the largest order.

4. *Stores.*—Many delays may occur through difficulty in obtaining stores, such as tubing, tools, rope, etc. The standardisation, stocking, and turn over of such stores at some central spot would save these delays in most cases.

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BATTLE HONOURS OF ROYAL ENGINEER UNITS.

(*Continued*).

Since the publication of the first lists of Battle Honours in the last *Royal Engineers Journal*, I have received the following letter which I have been asked to publish in full in substitution of the *Notice* which appeared on page 237 of that *Journal*. Arrangements have now been made for the lists to be completed, but Col. Pridham's lists dealing with the Gallipoli Campaign will not be published until all the lists referring to the Campaign in France have been completed.

Ed. *R.E. Journal*.

The War Office, 27, Pilgrim Street, Ludgate Hill, London, E.C.4.
(Medal Branch, A. G. 10.) 8th July, 1925.

To the *Secretary, Institution of Royal Engineers*.

DEAR SIR,—You will have noticed that from time to time notifications of the award of Battle Honours to Regiments of Cavalry and Infantry have been appearing in Army Orders and in the Press.

This work is now completed after a great deal of research, and Regiments have been awarded Battle Honours in strict accordance with the terms laid down by a "Battles Nomenclature Committee" appointed in August, 1919. This Committee tabulated Theatres of War and Actions with a definite system of nomenclature denoting their relative importance, and defined the geographical and chronological limits of each Action. The Battles Nomenclature Committee's report is an official publication and can be obtained through any newsagent for two shillings.

From the tabulated Theatres of War and Actions a list of those for which Battle Honours might be awarded to Infantry and Cavalry was drawn up by a special Battle Honours Committee and accepted by the Army Council. This list is enclosed for your information.

Although the grant of individual Battle Honours is not applicable to Royal Engineer units, since the motto "Ubique" covers every theatre of operations, it could not fail to be of very great interest to the Corps if complete lists were compiled to show what Battle Honours would have been gained by the several units which participated.

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At first Colonel G. R. Pridham, D.S.O., O.B.E., and afterwards Lieutenant Colonel J. D. Monro, O.B.E., have devoted their entire time for some months in collecting information for the War Office as to the eligibility of Engineer units for Battle Honours, on the same lines as laid down and approved by the Army Council for Infantry and Cavalry, and I am authorised to enclose a copy of this work so far as it is completed, and to state that though their task has been extremely difficult, the movement of every unit has been carefully tabulated.

I am to ask if the Committee would be agreeable to publish a copy of this explanatory letter in *The Royal Engineers Journal* with the lists of units, which would have been awarded Battle Honours, as an appendix in small type.

We invite publication now as criticism would assist in the elimination of any small errors, and the movements of each unit should be of general interest. The lists will in any case form a backbone for further regimental history.

Yours faithfully,

G. T. BRIERLEY,

Colonel.

The Secretary,
Institution of Royal Engineers,
Chatham.

THEATRE OF WAR HONOURS.

France and Flanders.
Italy.
Macedonia
Gallipoli.
Egypt.
Palestine.
Mesopotamia.
Persia.
N.W. Frontier India.
Baluchistan.
Murman.
Archangel.
Siberia.
E. Africa.
S.W. Africa.
Cameroons.

BATTLE HONOURS.

Mons.
Le Cateau.
Retreat from Mons.
Marne 1914.
Aisne 1914.
Antwerp
La Bassée 1914.
Messines 1914.
Armentières 1914.
Ypres 1914.
Langemarck 1914.
Gheluvelt.
Nonne Bosschen.
Festubert 1914.
Givenchy 1914.
Neuve Chapelle.
Hill 60.
Ypres 1915.
Gravenstafel.
St. Julien.
Frezenberg.
Bellewaarde.
Aubers.
Festubert 1915.
Hooge 1915.
Loos.
Mount Sorrel.
Somme 1916.
Albert 1916.
Bazentin.
Delville Wood.
Pozières.
Guillemont.
Ginchy.
Flers-Courcelette.
Morval
Thiepval.
Le Transloy.
Ancre Heights.
Ancre 1916

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Bapaume 1917.
Arras 1917.
Vimy 1917.
Scarpe 1917.
Arleux.
Oppy.
Bullecourt.
Hill 70.
Messines 1917.
Ypres 1917.
Pilckem.
Langemarck 1917.
Menin Road.
Polygon Wood.
Broodseinde.
Poelcappelle.
Passchendaele.
Cambrai 1917.
Somme 1918.
St. Quentin.
Bapaume 1918.
Rosières.
Arras 1918.
Avre.
Ancre 1918.
Villers Bretonneux.
Lys.
Estaires.
Messines 1918.
Hazebrouck.
Bailleul.
Kemmel.
Béthune.
Scherpenberg.
Aisne 1918.
Marne 1918.
Soissonnais-Ourcq.
Tardenois.
Amiens.
Somme 1918.
Albert 1918.
Bapaume 1918.
Arras 1918.
Scarpe 1918.
Drocourt-Quéant.
Hindenburg Line.
Havrincourt.
Epéhy.
Canal du Nord.
St. Quentin Canal.
Beaurevoir.
Cambrai 1918.
Ypres 1918.
Courtrai.
Selle.
Valenciennes.
Sambre.
Pursuit to Mons.

Isonzo.
Piave.
Vittorio Veneto.

Kosturino.
Struma.

Doiran 1917.
Doiran 1918.

Helles.
Landing at Helles.
Krithia.
Anzac.
Landing at Anzac.
Defence of Anzac.
Suvla.
Sari Bair.
Landing at Suvla.
Scimitar Hill.

Agagiya.
Suez Canal.
Rumani.
Rafah.

Gaza.
El Mughar.
Nebi Samwil.
Jerusalem.
Jaffa.
Jericho.
Jordan.
Tell 'Asur.
Megiddo.
Sharon.
Nablus.
Damascus.

Aden.

Basra.
Shaiba.
Kut al Amara 1915.
Ctesiphon.
Defence of Kut al Amara.
Tigris 1916.
Kut al Amara 1917.
Baghdad.
Khan Baghdadi.
Sharqat.

Merv.
Baku.

Troitsa
Dukhovskaya.

Tsingtao.
Herbertshöhe.

Kilimanjaro.
Behobeho.
Narungombe.
Nyangao.

Gibeon.

Kamina.

Duala.
Garua.
Banyo.

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NEUVE CHAPELLE. 10TH—13TH MARCH, 1915.

Unit.	Formation.	E.	Remarks.
54th Fld. Co.	7th Div.	E.	
55th ,, ,,	,, ,,	,,	
2nd Highland Fld. Co.	,, ,,	,,	
7th Sig. Co	,, ,,	,,	War Diary missing. Presumptive evidence.
2nd Fld. Co.	8th. ,,	,,	
15th ,, ,,	,, ,,	,,	With 23rd Inf. Bde.
1st Home Counties Fld. Co.	,, ,,	,,	
8th Sig. Co.	,, ,,	,,	
20th Co. 3rd S. & M.	Lahore Div.	,,	
21st ,, ,, ,,	,,	,,	
Lahore Divl. Sig. Co.	,,	,,	Lines to Brigades within area.
3rd Co. 1st S. & M.	Meerut Div.	,,	
4th ,, ,, ,,	,,	,,	
Meerut Divl. Sig. Co.	,,	,,	Lines to Brigades within area.
1st Siege Co. R. Anglesey R.E.	IVth Corps.	,,	

Verifications.
IVth Corps. and Indian Corps Signals.
1st Army Signals not present.

HILL 60. 17th—22nd APRIL, 1915.

Unit.	Formation.	E.	Remarks.
59th Fld. Co.	5th Div.	E.	
1/2nd Home Counties Fld. Co.	,,	,,	
5th Div. Sig. Co.	,,	,,	Communications maintained to Hill 60 during battle.
171st Tunnelling Co.	Army Troops	,,	

YPRES 1915. 22nd APRIL—25th MAY.

Unit.	Formation.	E.	Remarks.
171st Tunnelling Co.	2nd Army	E.	
2nd Bridging Train	,,	,,	
2nd Siege Co. R. Anglesey R.E.	Vth Corps.	,,	
4th Siege Co. R. Monmouth R.E.	,,	,,	
Vth Corps Signals	,,	,,	
IInd Corps Signals	2nd Corps	D.	
1st Fld. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	Communications to Brigades.
2nd Fld. Sqdn.	2nd Cav. Div.	,,	
2nd Sig. Sqdn.	,,	,,	No diary. Presumptive evidence.
3rd Fld. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	
9th Fld. Co.	4th Div.	,,	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	Communications to Brigades.
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
5th Sig. Co.	,,	,,	Communication to Brigades.
17th Fld. Co.	27th Div.	,,	

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Bapaume 1917.
Arras 1917.
Vimy 1917.
Scarpe 1917.
Arleux.
Oppy.
Bullecourt.
Hill 70.
Messines 1917.
Ypres 1917.
Pilckem.
Langemarck 1917.
Menin Road.
Polygon Wood.
Broodseinde.
Poelcappelle.
Passchendaele.
Cambrai 1917.
Somme 1918.
St. Quentin.
Bapaume 1918.
Rosières.
Arras 1918.
Avre.
Ancre 1918.
Villers Bretonneux.
Lys.
Estaires.
Messines 1918.
Hazebrouck.
Bailleul.
Kemmel.
Béthune.
Scherpenberg.
Aisne 1918.
Marne 1918.
Soissonnais-Ourcq.
Tardenois.
Amiens.
Somme 1918.
Albert 1918.
Bapaume 1918.
Arras 1918.
Scarpe 1918.
Drocourt-Quéant.
Hindenburg Line.
Havrincourt.
Epéhy.
Canal du Nord.
St. Quentin Canal.
Beaurevoir.
Cambrai 1918.
Ypres 1918.
Courtrai.
Selle.
Valenciennes.
Sambre.
Pursuit to Mons.

Isonzo.
Piave.
Vittorio Veneto.

Kosturino.
Struma.

Doiran 1917.
Doiran 1918.

Helles.
Landing at Helles.
Krithia.
Anzac.
Landing at Anzac.
Defence of Anzac.
Suvla.
Sari Bair.
Landing at Suvla.
Scimitar Hill.

Agagiya.
Suez Canal.
Rumani.
Rafah.

Gaza.
El Mughar.
Nebi Samwil.
Jerusalem.
Jaffa.
Jericho.
Jordan.
Tell 'Asur.
Megiddo.
Sharon.
Nablus.
Damascus.

Aden.

Basra.
Shaiba.
Kut al Amara 1915.
Ctesiphon.
Defence of Kut al Amara.
Tigris 1916.
Kut al Amara 1917.
Baghdad.
Khan Baghdadi.
Sharqat.

Merv.
Baku.

Troitsa
Dukhovskaya.

Tsingtao.
Herbertshöhe.

Kilimanjaro.
Behobeho.
Narungombe.
Nyangao.

Gibeon.

Kamina.

Duala.
Garua.
Banyo.

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ST. JULIEN. 24th April—4th May, 1915.

Unit.	Formation.	E.	Remarks.
171st Tunnelling Co.	2nd Army	E.	
2nd Siege Co. R. Anglesey R.E	Vth Corps	,,	
4th Siege Co. R. Monmouth R.E.	,,	,,	
Vth Corps Signals	,,	,,	
IInd Corps Signals	IInd Corps	D.	
1st Fld. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	D.	
2nd Fld. Sqdn.	2nd Cav. Div.	E.	
2nd Sig. Sqdn.	,,	,,	
3rd Fld. Sqdn.	3rd Cav. Div.	,,	
9th Fld. Co.	4th Div.	,,	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
17th Fld. Co.	27th Div.	,,	
1/1st Wessex Fld. Co.	,,	,,	
1/2nd Wessex Fld. Co.	,,	,,	
27th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
38th Fld Co.	28th Div.	,,	
28th Sig. Co.	,,	,,	
1/1st Northumbrian Fld Co.	50th Div.	,,	
1/2nd Northumbrian Fld. Co.	,,	,,	
	,,	,,	
50th Northumbrian Fld. Co.	,,	,,	
20th Co. 3rd S. & M.	Lahore Div.	,,	
21st Co. ,,	,,	,,	
Lahore Div. Sig. Coy.	,,	,,	
1st Canadian Fld. Co.	Canadian Div.	,,	
2nd ,, ,,	,,	,,	
3rd ,, ,,	,,	,,	
Canadian Sig. Co.	,,	,,	
54th Fld. Co.	7th Div.	,,	
55th Fld.	,,	,,	
2nd (Works) Cornwall Fortress Co.	G.H.Q.	,,	
1/1st Wilts. Fortress Co.	IInd Corps	D.	Diary missing.

FREZENBERG. 8th—13th May, 1915.

Unit.	Formation.	E.	Remarks.
171st Tunnelling Co.	2nd Army	E.	
2nd Bridging Train	,,	,,	
2nd Siege Co. R. Anglesey R.E.	Vth Corps	,,	
4th Siege Co. R. Monmouth R.E.	,,	,,	
Vth Corps Signals	,,	D.	
IInd Corps Signals	IInd Corps	,,	
1st Fld. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
3rd Fld. Sqdn.	3rd Cav. Div.	,,	
3rd Sig. Sqdn.	,,	,,	

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FREZENBERG: 8th—13th MAY, 1915.

Unit.	Formation.	E.	Remarks.
9th Fld. Co.	4th Div.	E.	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
17th Fld Co.	27th Div.	,,	
1/1st Wessex Fld. Co.	,,	,,	
1/2nd Wessex Fld. Co.	,,	,,	
27th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
38th Fld. Co.	28th Div.	,,	
28th Sig. Co.	,,	,,	
1/1st Northumbrian Fld. Co.	50th Div.	,,	
1/2nd Northumbrian Fld. Co.	,,	,,	
50th (Northumbrian) Fld. Co.	,,	,,	
1/1st Wilts. Fortress Co.	IInd Corps	D.	No diary.

BELLEWAARDE. 24th—25th MAY, 1915.

Unit.	Formation	E.	Remarks.
171st Tunnelling Co.	2nd Army	E.	
2nd Siege Co. R. Anglesey R.E.	Vth Corps	,,	
4th Siege Co. R. Monmouth R.E.	,,	,,	
Vth Corps Signals	,,	D.	
IInd Corps Signals	IInd Corps	D.	
1st Fld. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
2nd Fld. Sqdn.	2nd Cav. Div.	,,	
2nd Sig. Sqdn.	,,	,,	No diary. Presumptive evidence.
3rd Fld. Sqdn.	3rd Cav. Div.	,,	
9th Fld. Co.	4th Div.	,,	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
17th Fld. Co.	27th Div.	,,	
1/1st Wessex Fld. Co.	,,	,,	
1/2nd Wessex Fld. Co.	,,	,,	
27th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
38th Fld. Co.	28th Div.	,,	
28th Sig. Co.	,,	,,	
1/1st Northumbrian Fld. Co.	50th Div.	,,	
1/2nd Northumbrian Fld. Co.	,,	,,	
50th Sig. Co. (Northumbrian)	,,	D.	Diary missing.
1/1st Wilts. Fortress Co.	IInd Corps	,,	No diary.

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AUBERS. 9th MAY, 1915

Unit.	Formation.	E.	Remarks.
173rd Tunnelling Co.	1st Army	E.	
25th Fortress Co.	IVth Corps	,,	
23rd Fld. Co.	1st Div.	,,	
26th Fld Co.	,,	,,	
1/1st Lowland Fld. Co.	,,	,,	
1st Div. Sig. Co.	,,	,,	
1/3rd London Fld. Co.	47th Div.	,,	
1/4th London Fld. Co.	,,	,,	
47th Sig. Co.	,,	,,	
54th Fld. Co.	7th Div.	,,	
55th Fld Co.	,,	,,	
1/2nd Highland Fld. Co.	,,	,,	
7th Sig. Co.	,,	,,	No Diary. Presumptive evidence.
2nd Fld. Co.	8th Div.	,,	
15th Fld. Co.	,,	,,	
1/1st Home Counties Fld. Co.	,,	,,	
8th Div. Sig. Co.	,,	,,	
20th Fld. Co. 3rd S. & M.	Lahore Div.	D.	
21st. Fld. Co. 3rd S. & M.	,,	E.	
Lahore Div. Sig. Co.	,,	,,	
3rd Co. 1st S. & M.	Meerut Div.	,,	
4th ,, ,,	,,	,,	
Meerut Sig. Co.	,,	,,	
5th Fld. Co.	2nd Div.	,,	
11th Fld. Co.	,,	,,	
2nd Div. Sig. Co.	,,	,,	
1st Siege Co. R. Anglesey R.E.	IVth Corps		
2/1st West Riding Fld. Co.	49th Div.		
Ist Corps Signals	Ist Corps	D.	
IVth Corps Signals	IVth Corps	E.	
Indian Corps Signals	Indian	D.	

Verifications.

Not present.

170 Tunnelling Co.
176 ,, ,,
31st Fortress Co.
1/1st E. Anglian Fld. Co.
1/1st Highland Fld. Co.
2/2nd ,, ,,
51st Sig. Co.
1st, 2nd & 3rd Canadian Fld. Co.
Canadian Sig. Co.
1st & 2nd Bridging Trains
29th Co.
2nd Cornwall Siege Co.
1st R. Monmouth Siege Co.
1/1st S. Midland Fld. Co.
171 and 175-174-172 Tunnelling Cos.
4th Co. R. Monmouth R.E.
2nd Siege Co. R. Anglesey R.E.
42nd Co.

FESTUBERT. 15th—25th MAY, 1915.

Unit.	Formation.	E.	Remarks.
170th Tunnelling Co.	1st Army	E.	
173rd Tunnelling Co.	,,	D.	Cannot verify from diary.
1/3rd London Fld. Co.	47th Div.	F.	
1/4th ,, ,,	,,	,,	
47th Sig. Co.	,,	,,	
54th Fld. Co.	7th Div.	,,	
55th Fld. Co.	,,	,,	
1/2nd Highland Fld. Co.	,,	,,	

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FREZENBERG: 8th—13th MAY, 1915.

Unit.	Formation.	E.	Remarks.
9th Fld. Co.	4th Div.	E.	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
17th Fld Co.	27th Div.	,,	
1/1st Wessex Fld. Co.	,,	,,	
1/2nd Wessex Fld. Co.	,,	,,	
27th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
38th Fld. Co.	28th Div.	,,	
28th Sig. Co.	,,	,,	
1/1st Northumbrian Fld. Co.	50th Div.	,,	
1/2nd Northumbrian Fld. Co.	,,	,,	
50th (Northumbrian) Fld. Co.	,,	,,	
1/1st Wilts. Fortress Co.	IInd Corps	D.	No diary.

BELLEWAARDE. 24th—25th MAY, 1915.

Unit.	Formation	E.	Remarks.
171st Tunnelling Co.	2nd Army	E.	
2nd Siege Co. R. Anglesey R.E.	Vth Corps	,,	
4th Siege Co. R. Monmouth R.E.	,,	,,	
Vth Corps Signals	,,	D.	
IInd Corps Signals	IInd Corps	D.	
1st Fld. Sqdn.	1st Cav. Div.	E.	
1st Sig. Sqdn.	,,	,,	
2nd Fld. Sqdn.	2nd Cav. Div.	,,	
2nd Sig. Sqdn.	,,	,,	No diary. Presumptive evidence.
3rd Fld. Sqdn.	3rd Cav. Div.	,,	
9th Fld. Co.	4th Div.	,,	
1/1st West Lancs. Fld. Co.	,,	,,	
4th Sig. Co.	,,	,,	
59th Fld. Co.	5th Div.	,,	
1/2nd Home Counties Fld. Co.	,,	,,	
2/1st N. Midland Fld. Co.	,,	,,	
17th Fld. Co.	27th Div.	,,	
1/1st Wessex Fld. Co.	,,	,,	
1/2nd Wessex Fld. Co.	,,	,,	
27th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
38th Fld. Co.	28th Div.	,,	
28th Sig. Co.	,,	,,	
1/1st Northumbrian Fld. Co.	50th Div.	,,	
1/2nd Northumbrian Fld. Co.	,,	,,	
50th Sig. Co. (Northumbrian)	,,	D.	Diary missing.
1/1st Wilts. Fortress Co.	IInd Corps	,,	No diary.

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AUBERS. 9th MAY, 1915

Unit.	Formation.	E.	Remarks.
173rd Tunnelling Co.	1st Army	E.	
25th Fortress Co.	IVth Corps	,,	
23rd Fld. Co.	1st Div.	,,	
26th Fld Co.	,,	,,	
1/1st Lowland Fld. Co.	,,	,,	
1st Div. Sig. Co.	,,	,,	
1/3rd London Fld. Co.	47th Div.	,,	
1/4th London Fld. Co.	,,	,,	
47th Sig. Co.	,,	,,	
54th Fld. Co.	7th Div.	,,	
55th Fld Co.	,,	,,	
1/2nd Highland Fld. Co.	,,	,,	
7th Sig. Co.	,,	,,	No Diary. Presumptive evidence.
2nd Fld. Co.	8th Div.	,,	
15th Fld. Co.	,,	,,	
1/1st Home Counties Fld. Co.	,,	,,	
8th Div. Sig. Co.	,,	,,	
20th Fld. Co. 3rd S. & M.	Lahore Div.	D.	
21st. Fld. Co. 3rd S. & M.	,,	E.	
Lahore Div. Sig. Co.	,,	,,	
3rd Co. 1st S. & M.	Meerut Div.	,,	
4th ,, ,,	,,	,,	
Meerut Sig. Co.	,,	,,	
5th Fld. Co.	2nd Div.	,,	
11th Fld. Co.	,,	,,	
2nd Div. Sig. Co.	,,	,,	
1st Siege Co. R. Anglesey R.E.	IVth Corps		
2/1st West Riding Fld. Co.	49th Div.		
Ist Corps Signals	Ist Corps	D.	
IVth Corps Signals	IVth Corps	E.	
Indian Corps Signals	Indian	D.	

Verifications.

Not present.

170 Tunnelling Co.
176 ,, ,,
31st Fortress Co.
1/1st E. Anglian Fld. Co.
1/1st Highland Fld. Co.
2/2nd ,, ,,
51st Sig. Co.
1st, 2nd & 3rd Canadian Fld. Co.
Canadian Sig. Co.
1st & 2nd Bridging Trains
29th Co.
2nd Cornwall Siege Co.
1st R. Monmouth Siege Co.
1/1st S. Midland Fld. Co.
171 and 175-174-172 Tunnelling Cos.
4th Co. R. Monmouth R.E.
2nd Siege Co. R. Anglesey R.E.
42nd Co.

FESTUBERT. 15th—25th MAY, 1915.

Unit.	Formation.	E.	Remarks.
170th Tunnelling Co.	1st Army	E.	
173rd Tunnelling Co.	,,	D.	Cannot verify from diary.
1/3rd London Fld. Co.	47th Div.	E.	
1/4th ,, ,,	,,	,,	
47th Sig. Co.	,,	,,	
54th Fld. Co.	7th Div.	,,	
55th Fld. Co.	,,	,,	
1/2nd Highland Fld. Co.	,,	,,	

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LOOS. 25th SEPTEMBER—7th OCTOBER, 1915.

Unit.	Formation.	E.	Remarks.
1/1st Lowland Fld. Co.	1st Div.	E	
1st Div. Sig. Co.	,,	,,	
73rd Fld. Co.	15th Div.	,,	
74th Fld. Co.	,,	,,	
91st Fld. Co.	,,	,,	
15th Div. Sig. Co.	,,	,,	
1/3rd London Fld. Co.	47th Div.	,,	
1/4th London Fld. Co.	,,	,,	
2/3rd London Fld. Co.	,,	,,	
47th Div. Sig. Co.	,,	,,	
55th Fld. Co.	Guards Div.	,,	
75th Fld. Co.	,,	,,	
76th Fld. Co.	,,	,,	
Guards Div. Sig. Co.	,,	,,	
69th Fld. Co.	12th Div.	,,	
70th Fld. Co.	,,	,,	
87th Fld. Co.	,,	,,	
12th Div. Sig. Co.	,,	,,	No diary. Presumptive evidence.
97th Fld. Co.	21st Div.	,,	
98th Fld. Co.	,,	,,	
126th Fld. Co.	,,	,,	
21st Div. Sig. Co.	,,	,,	
103rd Fld. Co.	24th Div.	,,	
104th Fld. Co.	,,	,,	
129th Fld. Co.	,,	,,	
24th Div. Sig. Co.	,,	,,	
3rd Co. 1st S. & M.	Meerut Div.	N.E.	
4th Co. 1st S. & M.	,,	E.	
Meerut Div. Sig. Co.	,,	,,	
81st Fld. Co.	19th Div.	,,	
82nd Fld. Co.	,,	N.E.	
94th Fld. Co.	,,	E.	
19th Div. Sig. Co.	,,	,,	

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PROFESSIONAL NOTES.

THE VICTAULIC PATENT PIPE JOINT.

Communicated by the R.E. Board.

The Victaulic pipe joint was described briefly in the *R.E. Journal* in 1921 (Vol. XXXIV, No. 5, p. 230); since that time the construction of the joint has been slightly modified, and it is now accepted throughout the tube trade.

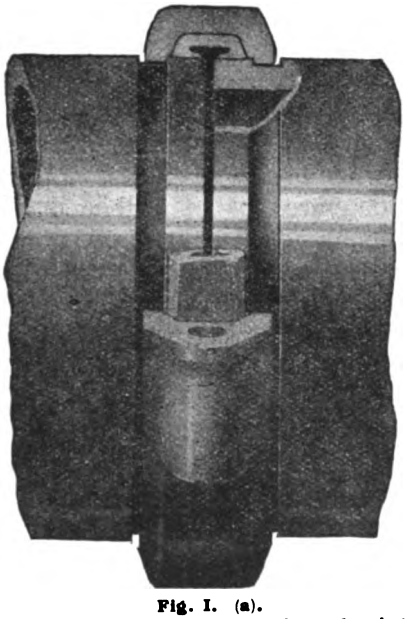

Fig. I. (a).
The Victaulic joint in part section; showing tubes with grooved ends.

The halves of the housing are now bolted together (before they were tapered on the outer diameter and retained by a keep-ring with a taper bore), but the essential "leak-proof" ring remains.

This ring, shown in Fig. I (*a*) and (*b*), has flexible inturned lips which are stretched on to the pipes and sealed by the internal fluid pressure; a supplementary grip is also exerted by the tightening of the housing.

Tubes for use with the joint have expanded or grooved ends, as shown in the sections Fig. I (*a*) and (*b*); they are supplied by the leading tube makers. Thin gauge tubing, in sizes up to 3″, can be expanded by hand—without pre-heating—with a portable tool supplied by the Victaulic Company. This is useful for making up lengths *in situ*.

Thick tubing may be grooved. The groove is shallow and about the same depth as an ordinary screw-thread; there are portable tools for this operation, and sizes up to 12″ bore can be grooved by hand, each tool generally having a range of about 2″. For any particular size

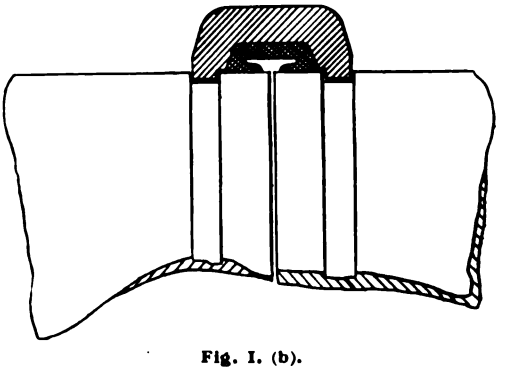

Fig. I. (b).

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of piping the housing differs slightly for expanded or grooved ends, on account of the variation in the diameters of the seating for the housing.

The shoulders of the tube, clearly shown in Fig. I (*a*) and (*b*), are loosely engaged by the housing. Clearance is provided radially and longitudinally so that, whilst still coupled positively together and with the flexible leak-proof ring sealing the joint, the pipe-ends can move longitudinally or make an angle, one with another.

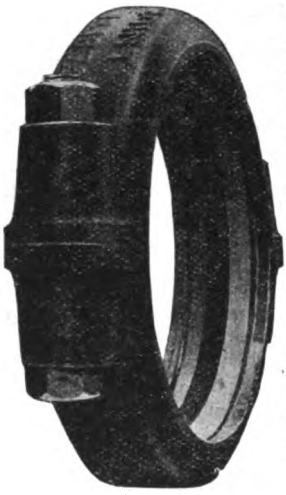

Fig. II.
A typical Victaulic joint

The joint needs no skilful fitting or adjustment. The seal does not depend upon tightness, as the joint is self-sealing; the degree of tightness is, therefore, independent of the skill of the fitter.

This simplicity of fitting saves a great deal of time when laying pipe-lines. In an emergency 400 yards of 2½" tubing have been laid at night by the light of oil lamps, the line being laid *and in use* in less than an hour. Further, the men who volunteered for the work are understood to have never seen a Victaulic joint before. The illustration (Fig. V), shows the flexibility of the line, to which is due, of course, a great deal of the saving in time, owing to there being no need for accurate alignment of the tubes. The flexibility is more clearly seen in Fig. VI, which shows a cast-iron main laid in a trench, and in Fig. IV, where the pipe-lines, laid in oil-fields, have been laid under conditions analagous to emergency service in the field.

A length of damaged pipe is very easily replaced, the time required being very much less than for screwed pipes; hence, on active

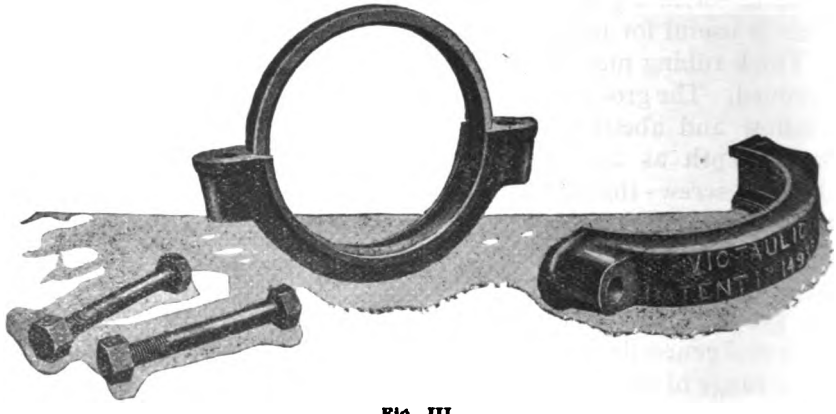

Fig. III.
Showing the parts of the joint.

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PROFESSIONAL NOTES.

THE VICTAULIC PATENT PIPE JOINT.

Communicated by the R.E. Board.

The Victaulic pipe joint was described briefly in the *R.E. Journal* in 1921 (Vol. XXXIV, No. 5, p. 230); since that time the construction of the joint has been slightly modified, and it is now accepted throughout the tube trade.

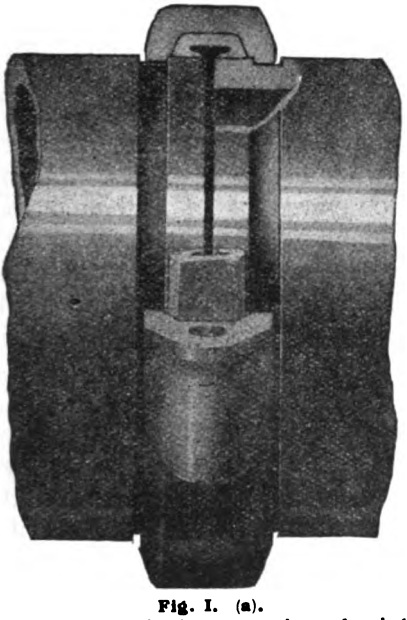

Fig. I. (a).
The Victaulic joint in part section; showing tubes with grooved ends.

The halves of the housing are now bolted together (before they were tapered on the outer diameter and retained by a keep-ring with a taper bore), but the essential "leak-proof" ring remains.

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Thick tubing may be grooved. The groove is shallow and about the same depth as an ordinary screw-thread; there are portable tools for this operation, and sizes up to 12" bore can be grooved by hand, each tool generally having a range of about 2". For any particular size

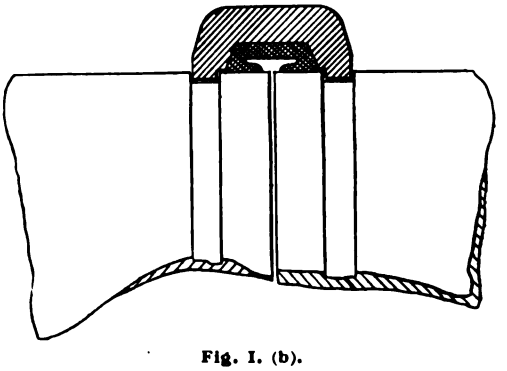

Fig. I. (b).

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of piping the housing differs slightly for expanded or grooved ends, on account of the variation in the diameters of the seating for the housing.

The shoulders of the tube, clearly shown in Fig. I (*a*) and (*b*), are loosely engaged by the housing. Clearance is provided radially and longitudinally so that, whilst still coupled positively together and with the flexible leak-proof ring sealing the joint, the pipe-ends can move longitudinally or make an angle, one with another.

Fig. II.
A typical Victaulic joint

The joint needs no skilful fitting or adjustment. The seal does not depend upon tightness, as the joint is self-sealing; the degree of tightness is, therefore, independent of the skill of the fitter.

This simplicity of fitting saves a great deal of time when laying pipe-lines. In an emergency 400 yards of $2\frac{1}{2}$" tubing have been laid at night by the light of oil lamps, the line being laid *and in use* in less than an hour. Further, the men who volunteered for the work are understood to have never seen a Victaulic joint before. The illustration (Fig. V), shows the flexibility of the line, to which is due, of course, a great deal of the saving in time, owing to there being no need for accurate alignment of the tubes. The flexibility is more clearly seen in Fig. VI, which shows a cast-iron main laid in a trench, and in Fig. IV, where the pipe-lines, laid in oil-fields, have been laid under conditions analagous to emergency service in the field.

A length of damaged pipe is very easily replaced, the time required being very much less than for screwed pipes; hence, on active

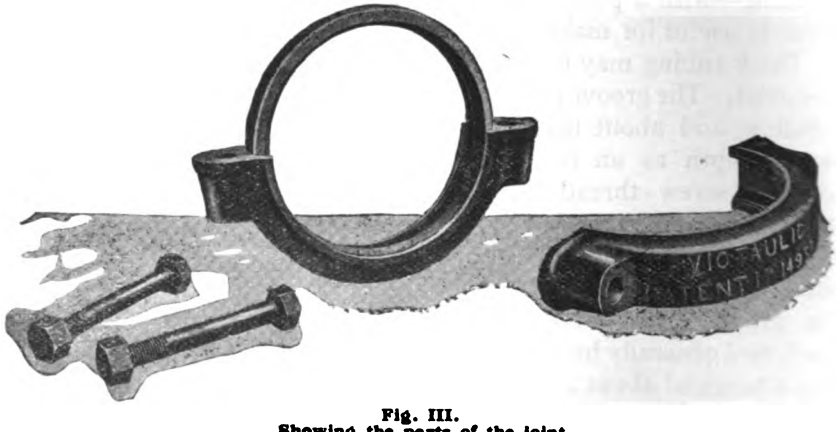

Fig. III.
Showing the parts of the joint.

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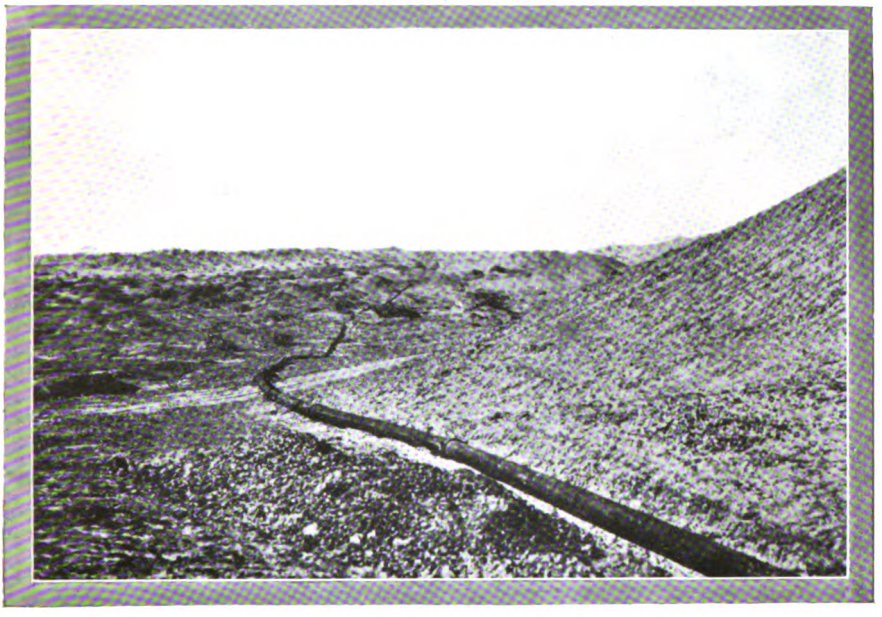

Fig. IV.

6" line carrying natural gas at pressures up to 250lbs. per square inch on the Peru oil-field of the London & Pacific Petroleum Co. (Standard Oil Co. of New Jersey). Other lines carry oil and salt water.

Fig. V.

At this colliery, 400 yards of 2½" were laid in less than an hour—by men who had never seen a Victaulic joint before. The occasion was an emergency, and the men were working in the dark.

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Fig. VI.

This photograph shows Victualic joints fitted on a 5in. cast iron main at the Harton Coal Company's Whitburn Colliery. It illustrates how the joints permit the pipes to be laid without any special alignment.

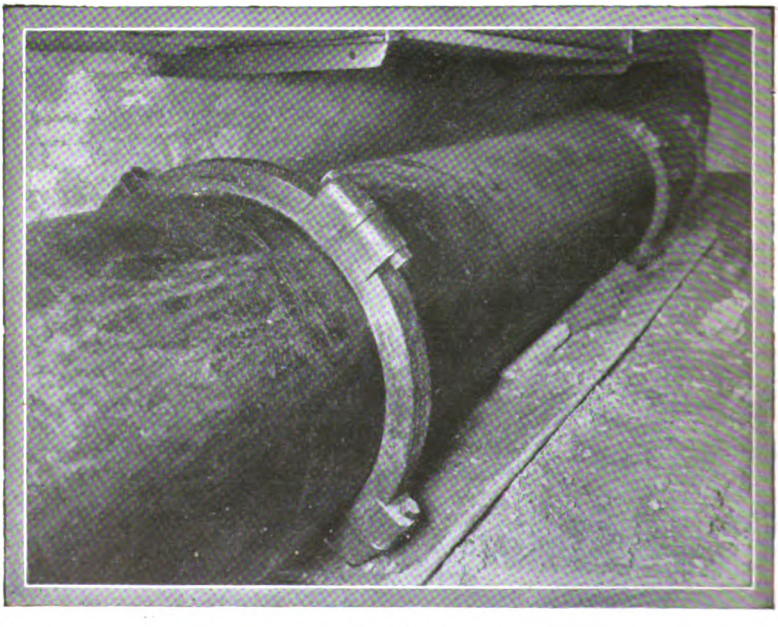

Fig. VII.

A 30in. main laid in a tunnel by the Metropolitan Water Board. Pressure 90 rounds; test pressure 170 pounds. In this case the housing is made in four parts to facilitate manufacture and fitting.

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Colonel Henry Vero Biggs, D.S.O.

Photograph by Elliott & Fry, Ltd.

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In February 1887, he was invalided from fever and sciatica brought on by bivouacking in the jungle in heavy rain. He had then been four years continuously under canvas or in bivouac, except for short periods of leave.

On returning to India he decided to revert to garrison duty with the Military Works Department, in view of his impending marriage to the daughter of Colonel C. H. Ewart, B.S.C.; but it was not without many regrets that he left his rough, campaigning life, for " the call of the wild " was always strong on him, and a search for big game, the more strenuous the better, was his ideal of a holiday.

He made a special study of the science of ballistics, as applied to sporting rifles. At that time a .577 express was considered the smallest rifle which could be safely used with tiger. Biggs was convinced from calculations that an equally deadly weapon could be made with a smaller bore, using a higher velocity, and he got an express rifle made to his specification. His ideas have been embodied in modern rifles.

For the next ten years he was employed in the Military Works in various large cantonments. Whatever his work was he did with his might what his hand found to do. " His reports and plans were marvels of completeness." Nor were his interests confined to his own branch of the service. In spite of the very heavy work involved in the execution of extensive building and engineering works, he found time to keep himself abreast of all military questions.

Major General S. H. Sheppard writes of him: " I always looked on him as one of the straightest and most loyal men I have ever met, and there was no man I would sooner have had with me in a tight place whether in war or in the face of a charging tiger. He was a Spartan in many ways ; and, in the days when I knew him in India, as hard as nails ; and the keenest *shikari* I have ever known, especially after big game. No trouble was too great and no day was too long, if he was after a " warrantable beast." With all, he was singularly human, and a great lover of nature, and I could not have wished for a more delightful companion on the many walks aud small expeditions with gun and rod, that I so often had with him."

When the Frontier troubles broke out in 1897 he joined the Khyber Column from leave, but was recalled ; but shortly afterwards he was appointed Adjutant with the Tirah Expeditionary Force.

He was present at Dargai, where after other attacks had failed, the Gordon Highlanders stormed the position in old fashioned style, to the tune of the bagpipes.

The enemy never " faced the music," again, but our columns were persistently and heavily sniped by men who were past-masters in scouting and shooting. It was not until our troops learned to play the enemy's game that we really got on terms with them. For

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MEMOIRS.

COLONEL HENRY VERO BIGGS, D.S.O.

Henry Vero Biggs, the fourth son of Colonel T. Biggs, R.A., of Wrington, Somerset, was born at Belgaum, India, in 1860. When he was five years old his mother died of cholera and he also nearly succumbed to it. Twenty years later he had another attack of the same disease in Baluchistan. Returning to England from Belgaum in 1865, he was educated at a private school, and in 1877 he passed 5th into the R.M.A., and thence into the Royal Engineers.

During his two years at the S.M.E. he made friends by whose intercourse his faith in God was strengthened. He then purposed with God's assistance that his work in the army should be done as a duty to God first, and then to his country. From that purpose he never swerved.

After a year on the Thames and Medway Defences he was posted to the Bombay Sappers and Miners in 1883. He served with them on the North West Frontier in Baluchistan for 2½ years. His company was first employed on road construction in the Bolan Pass, but in 1884, when the Russian advance north of Herat was beginning to seriously threaten the frontier of Afghanistan, it was decided to build a permanent broad gauge railway to Quetta by the Hurnai Pass. Major General Sir James Browne (R.E.) was put in charge of the work. with Lieut. G. K. (afterwards Major General Sir George) Scott-Moncrieff as his personal assistant. Seven companies of Sappers and Miners, including Biggs' company, were sent to help in the work at one of its most difficult points in the Chappar Rift, where the railway passed by a series of tunnels and a lofty bridge through a precipitous gorge.

The railway was rapidly completed in the face of tremendous difficulties of transport, climate and disease, and through formidable engineering obstacles. In a wild scene of desolation named The Mud Gorge the shale soil was so hard that it had to be blasted, yet it literally melted when exposed to rain, and the whole railway slid down the side of the valley. In this work Biggs took his full share, in spite of a slight attack of cholera.

He also took part as a Field Engineer in the Zhob Valley Expedition. in which there was considerable hardship, though no fighting. On the outbreak of war with Burma in the autumn of 1885, Biggs joined the Expeditionary Force, and took part in much of the fighting before and after the capture of Mandalay.

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Colonel Henry Vero Biggs, D.S.O.

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Talbot, his father's valued assistant, and began to practise as a Consulting Engineer; he was responsible with these two gentlemen for the design of the tramways in Liverpool, Newcastle-on-Tyne and Leeds, for the electric lighting scheme at St. Helens, and for the electric supply schemes at Crewe, Ealing, Faversham and Sale.

The adoption of the course which he pursued required high courage and rare adaptability, both these qualities he possessed in abundance. The step he took was possible perhaps only by reason of the fact that he had absorbed a good deal of engineering during his intercourse with his father, with whom he had been a close companion. He not only succeeded in the practical aspect of his new profession but soon found in it material for scientific research. The three partners read a Paper in 1902 before the Institution of Civil Engineers on "Electric Tramways," in which, *inter alia*, particulars of his experiments in electrolysis were given; for his contribution to this Paper he was awarded the Watt Gold Medal by the Council of the Institution of Civil Engineers.

He was appointed to the Chair of Mechanism and Applied Mechanics in the University of Cambridge in 1903, and took up his duties in the Michaelmas Term of that year. The appointment involved his assuming the charge of the Cambridge Electrical School, which had under his brother-in-law, Professor Alfred Ewing, F.R.S. (afterwards Sir Alfred Ewing, K.C.B.), by that time become an exceedingly important section of the University. He now found a wider scope than had been open to him previously, for research work, and at once entered upon a period of remarkable productivity. The development of the gas-engine and other internal-combustion engines appealed strongly to him, he invented an optical indicator which proved itself to be a most effective instrument for revealing what happens in the cylinder of such engines. He investigated problems of heat, flow and temperature distribution; he also gave much time to the study of gaseous explosions, the devices used in this research were of great ingenuity, and the experiments were prosecuted with conspicuous thoroughness. He also invented a new type of torsion meter for the measurement of horse-power, which was widely used with great success. He contributed many valuable papers to the Royal Society, The Institution of Civil Engineers, The Iron and Steel Institute and the British Association; for a paper on "Heat-flow and temperature-distribution in the gas-engine," read before The Institution of Civil Engineers in 1908, the Council of that Institution awarded him the Telford Gold Medal. His published works included a memoir of his father, written as a preface to the reprint of John Hopkinson's Collected Papers, as well as many accounts of his own researches.

He took a leading part in the work of several Research Committees; *inter alia*, he served jointly with Mr. Dugald Clerk, D.Sc., F.R.S.

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(afterwards Sir Dugald Clerk, K.B.E.), as Secretary of the British Association Committee on Gaseous Explosions; he was an original member of the Advisory Committee set up in connection with the establishment of the Department of Scientific and Industrial Research; he acted as Secretary to the Committee of Engineering Experts appointed by the Royal Society to advise on problems of the Great War; he served on the panel of Lord Fisher's Board of Invention and Research.

He took a keen interest in the Volunteer movement, and early in his career joined the Volunteer Force. He was given a Commission in the Royal Engineers (Volunteers) in March, 1896, and posted to the Submarine Miners (The Tyne Division); he was promoted Captain in August, 1897, and transferred to the branch of the Corps known at the time as "The Electrical Engineers," a unit of the Royal Engineers (Volunteers), which was raised by his father, who was its first commanding officer. He received promotion to the rank of Major in the branch last mentioned in September, 1903. On the re-organization of the Electrical Engineers in June, 1907, on a divisional basis, he was posted to the London Division. On the creation of the Territorial Force under Lord Haldane's Re-organisation Scheme in April, 1908, he was transferred to the Unattached List of this Force, and, in January, 1909, was posted to the Cambridge University Officers' Training Corps. He did much to promote the interest of the Corps, and, on his initiative, the Military Authorities formed No. 1 Fortress Company of the Engineer branch of the University Corps, a unit of which he became the first Commanding Officer.

On the declaration of war in August, 1914, he was mobilised and relinquished his ordinary activities; he was appointed Instructor in Field Fortification at the School of Military Engineering, Chatham, on October 11, and held this appointment until the spring of 1915, when he went to the Admiralty to undertake important work on wireless telegraphy. Whilst employed at Whitehall, he became a member of the various technical committees as they were formed by the Board of Admiralty and during the period of his service under the Board, devised a means of protecting ships against torpedo attack.

In November, 1915, he received an appointment as Staff Captain in the Aircraft Equipment Directorate of the War Office, being employed under the Director-General of Military Aeronautics, and thus was established his first official connection with the Royal Flying Corps. He became responsible for both the design and supply of bombs, bomb-gear, guns and ammunition. A great part of the experimental work for the Flying Corps was at the time being carried out both at the manufacturers' works as well as at the central Flying School, Upavon (Wilts.). The combination of experimental and

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good fortune to be put over him in an appointment, to which my previous record would hardly have entitled me; but the receipt of a most charming letter of welcome from my old friend, with others of a like nature from brother officers, gave me a happiness, which only those who have felt the true friendship of our Corps can rightly value. I had then many opportunities of seeing his work again, and of sharing in the quiet happiness of his home, when staying with or near him. His work was always of the highest order and of most extraordinary thoroughness in every detail, evincing the method and care he bestowed on his every pursuit.

" Biggs, as a soldier, should have gone to a far higher place, but he never pushed his claims, nor attempted to obtain promotion or credit for the work he did. As a sportsman he was *facile princeps* of all whom I have ever met. A great student of ballistics, as his published papers show, he arrived in India with theories of his own, which he was eager to prove. At Mount Abu, soon after his arrival, he wanted above all things to decide whether he was right in believing that to stop a charging tiger with a hollow bullet, it was necessary to let him come within 6 yards from the muzzle of his rifle. His theories made people regard him as almost a dangerous lunatic, but they soon changed their minds.

" Going out alone with a *shikari* to a place where a tiger was located, he arranged to have the animal beaten out to him, while he placed himself standing on foot under a single palm tree in the open. The tiger came out and was passing by, but catching sight of the sportsman as he looked round, he charged. I have seen the skull and skin of the great tiger, with the bullet straight between the eyes. The *shikari* said that as the tiger fell head over heels at his feet the *sahib* took a measuring tape from his pocket and quietly measured the distance, saying " Yes, 6 yards."

" How on another occasion he crawled into thick scrub after a wounded leopard and finished him in the same way, is only one of many stories told of him. Out of one rocky hill alone near Secunderabad he got five leopards, which he pursued on foot. Many tigers fell to his unerring aim. He was a man of extraordinary courage, self reliance and rare purpose, with behind it all a strong faith that served him to the end, in the last days of his painful illness.

" For some time our friendship has been renewed, when we were both on the shelf; and looking back over the long range of years, I see always the picture of a true, loyal and steadfast man, unswerving in his purpose of seeing the right, and of doing it without thought of self.

" Biggs was a whole hearted Sapper of whom the Corps may well be proud."

J. A. GIBBON.

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machine "crashed" near Hainault Farm, Paston, Essex, and in the fall he was killed, probably instantaneously.

For his distinguished services in the War, he was created a Companion of the Order of Saint Michael and Saint George (*London Gazette*, January 24, 1917), and his name was brought to the notice of the Secretary of State for War (*London Gazette*, January 25, 1917). Age 44 years 7 months.

* * * * * * *

He possessed an obviously forceful personality, yet a notable characteristic was his unruffled kindliness and serenity in the most trying circumstances. He was at all times a cheerful comrade, and quickly won the liking, confidence and respect of all with whom he came into contact.

In his memory and that of his brother Cecil, who died of wounds received in Flanders towards the end of 1915, there has been founded by members of the family and friends, at Cambridge University, 'The Hopkinson Lectureship in Thermo-Dynamics," a Lectureship which will, no doubt, be eventually converted into a Professorship.

He married, at St. Mary Abbots Church, Kensington, on December 31st, 1903, Mariana Dulce, the eldest daughter of Alexander Siemens of Campden Hill Court, Kensington; he is survived by his widow and a family of seven daughters.

He was elected a Fellow of the Royal Society in 1910, and was serving on its Council, to which he was elected in November, 1917, at the date of his death. He was elected a Member of the Institution of Civil Engineers in December 1904, and a Member of The Institution of Mechanical Engineers in the same year. He had become an Associate Member of the Institution of Electrical Engineers in 1897, a Member in 1903, and was a Member of its Council 1914-16.

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Colonel Bertram Hopkinson, C.M.G.

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BOOKS.

WAZIRISTAN 1919-20.

By H. DE WATTEVILLE, B.A. OXON., *p.s.c.*, late Lt.-Col. R.A. and General Staff. (Constable and Co., Ltd. Price 10/6.)

In his acknowledgment the author confesses to never having served on the North West Frontier of India. In spite of this handicap, he has succeeded in drawing a very accurate picture of the country in that part of the world and of the fighting that took place in it.

Not the least interesting part of the book is contained in the first four chapters which describe the country, its people and its history since the first Waziristan campaign in 1860, as well as the events leading up to the inception of the 1919 campaign. These chapters deserve close study by all who are interested in the politics of the North West Frontier of India; in them are described, clearly and fearlessly, the factors which have made for trouble in the past, some of which have still to be counted with, such as the miserable economic conditions at home which drive the Mahsud to raiding as a livelihood, the activities of the Soviet government in Afghanistan and the persistent intrigues against British interests in Waziristan by the Afghans. The obvious lesson, which is the keystone of the present policy of the Government of India, is admirably stated on page 10 in the words "the enforcement of more peaceful modes of life in Waziristan had long shown itself to be essential if India was to be considered secure against Afghan machinations among these wild people." Chapter III contains a summary of the various military operations carried out in Waziristan from 1860 up to the close of the Great War, and it closes with a reasoned appreciation which clearly shows the futility of attempting to achieve permanent results by means of what is colloquially termed the "burn and scuttle" frontier expedition. Control of the country from within its borders was an obvious, if costly, solution of the problem, and the late Lord Curzon's policy of garrisoning places like Wana and the upper Tochi Valley with tribal militias showed the first beginnings of giving such a policy a trial. That this policy broke down in 1919 at the time of the 3rd Afghan War, was not due to its inherent weakness, but to the methods adopted of putting it into practice. The tribal militias were located in the right places, but the proximity of reinforcements of regular troops was and is a *sine qua non*, if these irregular troops are expected to remain loyal in time of trouble. Chapter IV describes clearly how and why these tribal militias failed, and the state of lawlessness that ensued all along the Bannu and Derajat border. Between the outbreak of the Afghan War in May, 1919, and the beginning of November of that year, nearly 200 raids had been carried out by the Wazirs and Mahsuds into British India; these had resulted in nearly 300 military and over 600 civilian casualties, not to mention the looting of large quantities of cattle, stores and money. The chapter ends with the significant words that "The time had now come for recourse to drastic measures for terminating this unending catalogue of violence and depredation."

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The action which the Government of India decided to take is outlined in Chapter V, and it is interesting to note that in the first instance there was no declared intention of permanent occupation being the ultimate objective of the Expedition. The exaction of reparations, and the construction of roads within the " protected area " were amongst the more important terms that were placed before the tribes concerned, and it was estimated that the enforcement of these terms would involve three separate military operations, viz., against the Tochi Wazirs, the Mahsuds and the Wana Wazirs, which were to be undertaken in the order named. For this purpose the Waziristan Force (which had been in existence for some months) was raised by the middle of November, 1919, to a strength of nearly 30,000 combatants and 35,000 non-combatants. These figures were subsequently increased to 41,800 and 37,900 respectively, but it is interesting to note that the " striking force," i.e., that portion available for action at the head of the L. of C., barely amounted to 8,500 combatants and 6,500 non-combatants, so great were the demands for L. of C. protection and supply. The remainder of this chapter gives interesting details on the subject of L. of C. organization and transport which constitute the main administrative problem of a frontier expedition.

The submission, without fighting, of the Tochi Wazirs simplified matters by enabling earlier action to be taken against the Mahsuds, and this submission of the Wazirs has an important bearing on their friendly attitude during the Razmak operations of 1922-23.

Chapter VII deals with the projected campaign against the Mahsuds and contains interesting discussions on the alternative lines of advance, the plans of operations and the policy to be adopted towards the Mahsuds. In this the author deals very clearly with the ultimate objective " which would satisfy the purposes of the Expedition," and logically arrives at the conclusion that nothing short of some form of permanent occupation of the country will achieve lasting results. This is the conclusion to which, after considerable vacillation, the Government of India eventually brought itself round. This Chapter is worthy of close study by those who are likely in the future to be confronted by similar problems.

Chapters VIII to XII deal with the actual operations in the Takki Zam (or as the author calls it, the Tank Zam) and the advance to Makin and Kaniguram. The fighting is well described and no attempt is made to minimise the defects from which the Indian Army was suffering at the time. The successes of the Mahsuds in the opening stages of the campaign in December, 1919, are described and the reasons of the failure of the Indian troops (for there were no British infantry present) are analysed. The reasons for these failures are not far to seek, being almost entirely due to lack of training. It must be remembered, in all fairness to the Indian Army, that since the Armistice it had, in a very large measure, carried on the policing of the Empire. The disbandment of the British Army had begun soon after the Armistice, and the re-constitution and training of its regular units had not, by the end of 1919, gone very far forward. The old and new units of the Indian Army were therefore carrying on, all over the world, work which, in part at any rate, should have fallen to the share of their British comrades. The increase in numbers of the Indian Army during the war, coupled with the loss of

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Colonel Bertram Hopkinson, C.M.G.

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of the stream in Southern Waziristan which eventually drains into the Shahur Tangi. The Khaisora is situated in Northern Waziristan and constitutes one of the main drainage systems immediately south of the Tochi River. These names are confusing in their similarity and the mistake is perhaps not unnatural.

The book forms a valuable addition to our none too large stock of literature on frontier warfare, and is one which all soldiers should study.

J.R.E.C.

PARIS, OR THE FUTURE OF WAR.

By CAPT. B. H. LIDDELL HART. (Kegan Paul.) 2/6.

WHEN a member of a profession writes on a professional subject for general consumption, his public, if themselves not well informed, are inclined to take all the statements and arguments as to a certain extent inspired. There rests on the author therefore a grave responsibility, and he should be careful that his statements are accurate and fair, and his conclusions sober and just. Captain Liddell Hart in his position as journalist apparently has forgotten the responsibility resting on him when he retains the military title of Captain. It is a pity that he allows his journalistic hyperbole to spoil a case with much of which every thinking soldier is in agreement. In enthusiasm over his subject the author loses perspective, and makes statements which will hardly bear cold investigation.

The attack is opened by a diatribe against the principles of war as the author imagines them accepted by the " military pundits " of the day. His references give an inaccurate impression of phrases of the regulations, which he entirely divorces from the context, and from the spirit exhibited on every page of the manuals of various military powers. For example, we are told that in the words of *Field Service Regulations*, the accepted military objective in war is the enemy's main forces on the battlefield. The author is endeavouring to show the blindness of the soldier to the moral objective, forgetting, or possibly not having read, the neighbouring paragraph which describes the first duty of the general staff as being " to appreciate the course of action which . . . . . will most rapidly influence the enemy people in the required direction. This demands . . . . . a careful study of the psychology of the enemy people, of their national characteristics, resources, and means of existence." Such a travesty of facts will be patent to the military student, but is mischievous in the hands of a less informed public.

To gain some idea of the author's ideal military brain it is amusing to note his attacks on the " military pundits " from " the Corsican vampire who drained the blood of Europe a century back," through Clausewitz " whose house was built on sand," to Marshal Foch who, among certain better qualities, displays " the recurring delusion of the military mind that the opposition to the Napoleonic theory must necessarily be dictated by mere sentimentalism." On the other hand he appears to laud the dictum of Marshal de Saxe, " I am not in favour of giving battle . . . . . I am even convinced that a clever general can wage war his whole life without being compelled to do so " !

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Having stressed the importance of the moral objective supported by the untenable hypothesis that the influenza epidemic of 1918, which he forgets struck America as seriously as any other nation, was due to years of strain and want, he passes on to the means by which the objective may be obtained. Though his criticicisms are mostly directed against military authorities, the means suggested are chiefly in the hands of the statesman rather than the soldier.

The author proceeds to examine the various arms, and the section referring to the future of air power is one of the best and most convincing in the book. He considers that sea and land weapons will only remain effective till the air weapon reaches maturity. In the meantime discussing naval and military power, he draws attention to the serious menace which the submarine fleet of France, coupled with an unfriendly Ireland, might prove.

With regard to the Army the author adds little to the views expressed by military leaders and writers of all countries as to the future of cross country movement. The importance of rapidity, and freedom of movement, of armoured vehicles is almost axiomatic. After discussing the economic aspect of war in the earlier pages of the book, and stating in the epilogue that " future wars will be waged by weapons which are the products of peace time industry," it is somewhat difficult to see how the huge amount of cross country transport necessary is to be provided, till the track vehicle is on demand in civil life.

The book which, as has been shewn, needs not the skill of a Paris to discern its vulnerable points, may be read with amusement and a certain amount of interest by the informed mind. In the hands of a less informed public it may achieve its presumable object of producing a terror of war in the future, but may also it is feared produce an impression that the ideas of military leaders are in a state of complete stagnation, which is altogether unjustified.

R.P.P.-W.

LA GRANDE GUERRE SUR LE FRONT OCCIDENTAL. Vol. XI. Bataille de la Somme (1 Juillet, 1916—1 Janvier, 1917) par le Général Palat. (Paris: Berger Levrault.) 20*fr.*

This volume is not up to the standard of the preceding ones. The narrative is somewhat slight and the more difficult to follow as only one general small scale map for the Somme is provided; it includes the latter part of the operations at Verdun—very properly, as they are dependent on what happened at the Somme. There is little information from German sources except extracts from the *communiqués* of the time. The account of the British operations is derived mostly from Sir D. Haig's despatches. Time after time the author emphasises the perfect accord between General Joffre and the British Commander-in-Chief and their respective staffs; and he makes the point that there was unity of command without having to resort to a written protocol, which the politicians introduced in 1918 in the hope of persuading the public that they had a share in winning the war.

The chapter dealing with the continued efforts of the parliamentarians—eventually successful—to oust Generals Joffre and Foch from their posts,

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The action which the Government of India decided to take is outlined in Chapter V, and it is interesting to note that in the first instance there was no declared intention of permanent occupation being the ultimate objective of the Expedition. The exaction of reparations, and the construction of roads within the " protected area " were amongst the more important terms that were placed before the tribes concerned, and it was estimated that the enforcement of these terms would involve three separate military operations, viz., against the Tochi Wazirs, the Mahsuds and the Wana Wazirs, which were to be undertaken in the order named. For this purpose the Waziristan Force (which had been in existence for some months) was raised by the middle of November, 1919, to a strength of nearly 30,000 combatants and 35,000 non-combatants. These figures were subsequently increased to 41,800 and 37,900 respectively, but it is interesting to note that the " striking force," i.e., that portion available for action at the head of the L. of C., barely amounted to 8,500 combatants and 6,500 non-combatants, so great were the demands for L. of C. protection and supply. The remainder of this chapter gives interesting details on the subject of L. of C. organization and transport which constitute the main administrative problem of a frontier expedition.

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practically all their original captains and subalterns, had left units in a low state of efficiency; many of the officers who had joined the Indian Army during the war were unable to speak the language of their men, and in consequence could not train them properly. The continual demand for more units meant insufficient individual training for the recruit, who, on joining his unit, often hardly knew how to load his rifle, still less how to fire it. It is not surprising then that some units, especially those drawn from the less warlike races of India, failed, and failed badly, when faced by the Mahsud, who combines great personal bravery with astonishing skill as a skirmisher. It is to the lasting credit of the Commander of the Derajat Column and of the British officers and Indian troops under him, that, starting with such a handicap,they succeeded in the end at defeating the Mahsud at his own game.

The most interesting features in the fighting in the Tank Zam were the co-operation of aeroplanes, the institution of permanent piquets for guarding the L. of C. and the employment of night advances to secure difficult ground—these are worthy of the close attention of students of frontier fighting. Chapter XIII deals with the operations against the Wana Wazirs in the Autumn of 1920; and Chapter XIV deals with the Razmak operations of 1922-23. The chief interest in the latter Chapter lies in the obvious improvement which had taken place in the fighting spirit and efficiency of the Indian Army since the beginning of the 1919 campaign; the author, however, fails to bring out the fact that the friendliness of the Wazirs materially assisted the British forces during these operations. The advance from the Tochi into the Khaisora Valley and thence on to the Razmak plateau took place through Wazir territory. Not only was there no fighting until Mahsud territory was reached, but the Wazirs actually assisted the regular troops in piqueting the route, and in finding escorts for the R.E. officers who preceded the column when engaged in reconnoitring the alignment of the motor road, the construction of which was one of the main objects of the Razmak Expedition.

The book concludes with chapters on "Modern artillery and military armament in frontier warfare," on "Aircraft in frontier warfare," and on the "General lessons of the Campaign of 1919-20." All three are well worthy of study, and the pith of the last chapter is contained in the following sentence, the truth of which is perhaps not as fully realised as it should be:—

"So it comes about that in operations of this nature the bludgeon methods applicable to mass fighting must yield to the finer art of individual combat. But even a high pitch of training adequate for warfare on the plain is hardly sufficient for this class of fighting. The soldier required for frontier warfare must be trained for the end in view."

The author has a pleasant style which makes his story easy to read; his criticisms are made in a very fair spirit, and he deduces sound lessons. The book is illustrated with air photographs, the oblique ones of which give an excellent idea of the type of country in which the fighting took place. There are one or two mistakes in proper names in the text:—for instance, on page 47 "General Matheson" should read "General Malleson." On page 36, the objective of the 1917 operations is stated to have been the Khaisora Valley; this should be spelt Khaisara, which is the name

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of the stream in Southern Waziristan which eventually drains into the Shahur Tangi. The Khaisora is situated in Northern Waziristan and constitutes one of the main drainage systems immediately south of the Tochi River. These names are confusing in their similarity and the mistake is perhaps not unnatural.

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By CAPT. B. H. LIDDELL HART. (Kegan Paul.) 2/6.

WHEN a member of a profession writes on a professional subject for general consumption, his public, if themselves not well informed, are inclined to take all the statements and arguments as to a certain extent inspired. There rests on the author therefore a grave responsibility, and he should be careful that his statements are accurate and fair, and his conclusions sober and just. Captain Liddell Hart in his position as journalist apparently has forgotten the responsibility resting on him when he retains the military title of Captain. It is a pity that he allows his journalistic hyperbole to spoil a case with much of which every thinking soldier is in agreement. In enthusiasm over his subject the author loses perspective, and makes statements which will hardly bear cold investigation.

The attack is opened by a diatribe against the principles of war as the author imagines them accepted by the "military pundits" of the day. His references give an inaccurate impression of phrases of the regulations, which he entirely divorces from the context, and from the spirit exhibited on every page of the manuals of various military powers. For example, we are told that in the words of *Field Service Regulations*, the accepted military objective in war is the enemy's main forces on the battlefield. The author is endeavouring to show the blindness of the soldier to the moral objective, forgetting, or possibly not having read, the neighbouring paragraph which describes the first duty of the general staff as being "to appreciate the course of action which . . . . . will most rapidly influence the enemy people in the required direction. This demands . . . . . a careful study of the psychology of the enemy people, of their national characteristics, resources, and means of existence." Such a travesty of facts will be patent to the military student, but is mischievous in the hands of a less informed public.

To gain some idea of the author's ideal military brain it is amusing to note his attacks on the "military pundits" from "the Corsican vampire who drained the blood of Europe a century back," through Clausewitz "whose house was built on sand," to Marshal Foch who, among certain better qualities, displays "the recurring delusion of the military mind that the opposition to the Napoleonic theory must necessarily be dictated by mere sentimentalism." On the other hand he appears to laud the dictum of Marshal de Saxe, "I am not in favour of giving battle . . . . . I am even convinced that a clever general can wage war his whole life without being compelled to do so"!

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Junot's conquest of Portugal, Murat's arrival in Madrid and the revolution which placed the crown of Spain on the head of Ferdinand VII, was published in 1914. The author now explains that post-war conditions have necessitated economies and certain curtailment, but nevertheless the present volume, which opens with Murat's suppression of the rising in Madrid on the 2nd May, 1808, in no case carries the narrative beyond the end of June. We have the exile of the royal family to Bayonne, the rising of the Spanish people in almost every village in the country—engineered by the priests at the bidding of Rome, in retaliation for Napoleon's ill-treatment of the Pope—the isolation of Dupont in Andalusia, the surrender of Admiral Rosily's fleet at Cadiz (so shortly to be followed by two more surrenders, Baylen and Cintra), Moncey's march to Valencia, outbreaks in the north and west, and finally Lefebre Desnoëttes' failure to capture Saragossa by assault. We hear little of British influence in the revolt, beyond the fact that the various *juntas* undoubtedly counted upon British support. The name of Commandant Grasset as author is sufficient guarantee that the story is well told, and we look with keen interest to its further development.

F.E.G.S.

STRATÉGIE DES TRANSPORTS ET DES RAVITAILLEMENTS.

Par le Général RAGUENEAU. (Berger Levrault). 6*fr.*

THIS book by the Military Chief of the French Railways during the war is a reprint of three articles which appeared in the *Revue Militaire Française* last year.

The greater portion of the book is devoted to an outline of the part played by the railways in France and to thoughts on the use of railways in a future war.

Both the French and the German concentrations were allowed to take place quite unmolested, but it is impossible to conceive of this happening again. If some lines are blocked, even temporarily, it seems essential that some should be left spare in the original programme to prevent the time-table getting hopelessly deranged.

Even before the concentration was completed railways were being used to shift formations from one point of the line to another. It is obvious that lack of depth in the original dispositions makes this manœuvre all the harder.

After the invader has advanced a certain distance, the defender, provided he has destroyed the railways in his retreat, manœuvres at a great advantage, as was shown at the Marne.

When the fronts had stabilised, both sides set to work to improve railway facilities. The great need felt by French and Germans alike was for more transverse lines behind their fronts.

Great emphasis is laid on the necessity for depth in communications. Failure to maintain this necessary depth and flexibility was one of the main causes of the German breakdown in Nov., 1918. Through over-confidence they had sited their Supply Depots too far forward.

Another point of interest and cause of failure was the presence in the

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centre of the German line of the Ardennes, a large area with poor railway communications.

Some lessons appear to be—

(1) Railways have strict limitations, but when these have been allowed for they afford a very accurate method of moving troops ;

(2) Railway authorities must be in close and continual touch with the General Staff and must always be looking ahead ;

(3) In the national mobilisation of man power, consideration must be given to the needs of the railways if this powerful weapon is to be used to its full extent.

Road transport, light railways and transportation by sea and air are also touched on.

The function of M.T. and light railways must always be to supplement and not to replace railways. With regard to M.T., the author considers that vehicles should be equally capable of carrying personnel or materiel, and that reserve groups of M.T. should be centralised under G.H.Q.

Transportation in war demands the most careful study. "The first principle of war organisation is mobility," *F.S.R.* 1 2 (2). In a future war the influence on strategy of communications will be as great even as that of armaments.

E. H. CLARKE, Major R.E.

LES DOCTRINES DANS LA PREPARATION DE LA GRANDE GUERRE.

By General ARTHUR BOUCHER. (Berger Levrault.) 8 *fr.*

THE object of General Boucher's book is to show that the principles of war have not changed since the earliest days of Military History, and that the application of these principles in the French plan of campaign for the Great War might have obviated the disasters of 1914. Since the war a great deal of justifiable criticism has been levelled at the original plan and its execution, but the critics have generally ignored the reasons for the formation of this plan. General Boucher traces, in some detail, the development of both the German and French plans between 1870 and 1914, culminating on the French side in the famous "Plan XVII." This portion of the book will probably be of the greatest interest to the student on Military History, especially in showing the dangers of a particular school of thought in the General Staff becoming so predominant, that the higher commanders have to conform to its theories.

After the disasters of 1870, the experience of the war was put to such good use by the French military authorities that, by 1896, when the Franco-Russian alliance was made public, Schlieffen, the German Chief of Staff, admitted that France was impregnable on the common frontier. It was on this basis that the plan of violating Belgian neutrality and overwhelming the French left was evolved, first by Schlieffen and later by the younger Moltke. In the meantime, radical changes were taking place, both in the French plan of campaign and in the doctrines which were installed into the French army. The prime movers in these changes were General Bonnal and Colonel Grandmaison, and their theories are subjected by the author to an impartial and detailed criticism which is well worth studying.

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General Bonnal, an instructor at the French War College, was responsible for the introduction of a fresh war plan based on the Napoleonic strategy of the " battalion square," which Bonnal considered the solution to all strategical problems. At the same time reserve formations were eliminated from the first line troops, on the theory that extra training was necessary till the soldier became a fighting machine. Thus the striking force at the outset of the war was reduced to a considerable inferiority as compared with the German first line army, in which reserve formations were actually employed. The disadvantages of Bonnal's plan are clearly set out ; but the chief lesson to be drawn from this portion of the book is the danger of attempting to find a short cut to victory in the methods of a great commander, rather than in his general application of the principles of war.

Colonel Grandmaison, who was Chief of the Operations section of the General Staff, developed the theory of the offensive " à outrance " as being essential in all operations. The immediate reason for this doctrine was the necessity for raising the morale of the French Army, which had suffered greatly from political dissensions ; but General Boucher shows quite clearly how this doctrine, combined with the teaching that artillery should only support an attack, without preparing for it, was one of the chief causes of the collapse of the French plan in 1914.

In the last part of the book, the assistance of one of the earliest leaders in history, Xenophon, is called in to criticise the French and German plans, and to give his solution of the French problem. This may seem rather far-fetched to a good many readers, but should not deter anyone from reading an excellent analysis of the French plan, which is made all the clearer by the chapters tracing its growth since 1870. At the same time it is made perfectly clear that the majority of the principles which governed the operations of the great commanders of antiquity were deliberately violated, and that the failure was mainly due to their violation. The author's criticisms are open to few objections, except perhaps where he suggests a concentrated offensive into Luxembourg, combined with a defensive on the rest of the front, as the correct action on the outbreak of war.

General Boucher's book can be thoroughly recommended, either as a bird's-eye view of the development of the French and German strategy at the outbreak of the Great War, or as a basis for the detailed study thereof.

H. A. J. P.

L'EFFONDREMENT DU PLAN ALLEMAND EN SEPTEMBRE, 1914.

General CAMON. (Berger Levrault. 8 *fr.*)

The three studies into which the book is divided are reprints of articles which from time to time appeared in the *Revue Militaire Française*. They are here collected to form a connected strategical study of the causes which led to the failure of the German plan of campaign in 1914.

In the first study the author discusses the plan of campaign and the history of its development ; the second deals with the execution of the

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plan and the causes of failure ; in the third General Camon asks whether the study of the Napoleonic campaigns is still of value, and proceeds to show how many successful strategical conceptions of the Great War followed closely the methods of Napoleon.

The " motif " recurring on almost every page is, that to follow strictly in the steps of the Great Master is the only sure road to success in war, and that adherence to the teachings of Clausewitz and the methods of Moltke was the primary cause of the failure of the German plan. The two systems, labelled " la manœuvre Napoléonienne " and " le schèma de Cannes " are shown constantly in conflict. The reiteration of the theme is somewhat disturbing to the reader and gives the impression that the author looks on the whole art of war as covered by one sealed pattern manœuvre. Briefly the two systems are—

(*a*) Manœuvre by one wing against the flank and rear of a demoralised enemy ;

(*b*) envelopment of both wings of the enemy forces leading to complete annihilation—conception of Cannae.

1ST STUDY—GENESIS OF THE GERMAN PLAN.—In this study General Camon traces the development of German strategic thought from Frederick II and Clausewitz to Moltke ; discusses the clash of opinion in Germany as to the merits of convergence on front and both flanks on the battlefield, as exemplified by Sadowa, the traditional Moltke manœuvre ; finally, describes the first and second plans of Schlieffen, discusses in detail the factors which led to his final plan of 1905, and ingeniously shows that by transposing appropriate names and numbers in Napoleon's proposals for the conduct of the campaign of 1806, written to his brother, the King of Holland, Schlieffen's plan is almost exactly similar in its main outlines.

Schlieffen's final plan allotted 37 Divisions and 5 Cavalry Divisions to the decisive wing, I, II and III Armies, leaving a weak force of 11 Divisions and 3 Cavalry Divisions in Alsace and Lorraine. He visualised the abandonment of much of this area, and the check of the French offensive on the fortified line Metz-Strasbourg. The French would then be so far compromised that any transfer of troops to the threatened left flank would be difficult. Molke, taking counsel of his fears, depletes the right wing by 11 Divisions to strengthen his VI and VII Armies and the force in East Prussia, and does not dismiss the possibility of an offensive by the left flank armies, a development which General Camon stigmatises as veering to the " conception of Cannae " and, therefore, in itself containing the germ of defeat.

2ND STUDY.—EXECUTION OF THE GERMAN PLAN.—General Camon now deals in detail with the operations culminating in the battle of the Marne and the German retreat to the Aisne. The action of the right wing armies is first discussed, familiar ground. He deduces eight reasons for the German failure on this wing, apportioning the responsibility to individuals in each case. They are—

(1) Moltke's initial error in strengthening the left wing at the expense of the right.

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(2) Failure to envelop the Belgian Army on the Gette—Moltke, Bulow and Von Hausen.

(3) Failure to envelop the British and French V Army on the Sambre—the same three are to blame.

(4) Moltke's error in sending two Corps to East Prussia prematurely.

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Above all, General Camon blames Schlieffen, who, he says, prepared a perfectly correct Napoleonic manœuvre, and afterwards spent the remainder of his life advocating the "conception of Cannae," double envelopment, thus inculcating an incorrect strategic outlook in the German Higher Command and Staff.

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3RD STUDY—THE VALUE OF STUDYING NAPOLEON'S CAMPAIGNS.—Napoleon's two systems of manœuvre are—

(*a*) manœuvre against the enemy's rear, of which General Camon says he has counted 27, including Lodi, Marengo, Ulm, Jena and Vilna;

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Military history may, therefore, be studied from two points of view: first that of historical interest as a matter of patriotic education in which the study of detail is only limited by powers of memory; secondly, that of technical interest, in which tactical details are valueless, but the eternal principles of war may still be studied and applied to the handling of armies at the present day.

The book contains a number of very indifferent sketch maps.

R.L.B.

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PRACTICAL ASTRONOMY.

By GEORGE L. HOSMER. (New York: John Wiley and Sons.) 13/6. pp. 270 + ix.

THIS is a handy and well-printed little book, which is intended, as the preface tells us, to serve the needs of civil engineering students, who are not likely to take up advanced astronomy. It deals chiefly with those observations which can be made with surveying instruments; the instruments in question being assumed to be the engineer's "transit," i.e., transit theodolite, and the sextant. The inclusion of the latter may, perhaps, be due to the fact that there is a chapter on nautical astronomy, in which a good account is given of the determination of position at sea by Sumner lines.

The author has adopted the laudable device of printing in small type all those paragraphs which are not essential for a first study of the subject. Paper and type are excellent.

Not much originality is to be expected, or desired, in an elementary text book. What is chiefly required is clearness of exposition, and this is to be found in the book under review. It is, generally speaking, up-to-date. Thus, the abolition of the difference between civil and astronomical time is noted; and a brief account is given of the determination of longitude by the receipt of wireless time signals. But this account is too sketchy to be of value to the explorer. The answer to this remark would, no doubt, be that the book was written with the engineer in mind and not the explorer. But from this point of view it is curious that some pages of small print should have been devoted to an account of the fixing of longitude by moon culminations, a method, which, as the author points out, is incapable of giving results of any accuracy. One would not, in fact, be surprised if the mean of a week's work at moon culminations were a mile in error.

An excellent feature is the relatively large space devoted to the determination of azimuth, with a view of emphasizing the importance to the engineer of using the meridian in his surveys; and another good feature is the discussion of the effect of errors, for instance in altitude, by differentiating the usual spherical formulæ.

C.F.C.

AERIAL SURVEYING BY RAPID METHODS.

By B. MELVILL JONES and Major J. C. GRIFFITHS. (Cambridge University Press, 1925.) Price 16/-.

HERE is a most welcome book. It can happen but seldom that so obvious a gap exists in the literature on any subject or that the peg, where it appears, should so exactly fit the hole. Surveying from air photographs is the joint labour of three craftsmen, the surveyor, the photographer, and the pilot. There is abundant literature under the first heading, enough, at the moment, under the second, and hitherto practically nothing under the third, and yet in the British Empire especially, we are most dependent upon the proper study of how navigation should be carried out for survey photography and upon a well reasoned diagnosis

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of the errors which are due to its conditions and methods. In Europe generally the problem is of a different nature. Surveys extend practically everywhere and it is new maps at medium and not small scales which are wanted. The resection methods to which the authors allude, but do not describe, must then be the rule in old civilisations. But in the Empire at large the problem is still that of the first maps for development and administration. We want quarter inch or half inch maps, and to use the camera economically for such a purpose is the main preoccupation of the moment to the photo-surveyor.

Canada, it is true, has tackled and solved the problem in the flat water and forest regions of the north west, and has done so by the happiest co-operation of surveyor and airman, but it does not follow that her methods will be equally applicable elsewhere. The surveyors of the Empire must in fact, study their own individual conditions and suit method to country and to revenue.

Glib proposals and estimates omitting such insignificant factors as scale and type of country have been common and have hindered rather than helped. One does not map a continent or even a colony by any one method. The surveyor has as many tools in his bag as the golfer and, like the latter, will not use his brassie in a bunker, his iron for a long shot on the pretty or confine himself for good and all to a cleek. Air photo surveying can only be helped along by a reasoned statement of the pros and cons and by pointing out those matters for which it has special economic value. If this book had, then, contained little else but its introduction it would still have been worth while.

The authors, practical pilots both, and peculiarly suited by temperament and occupation to research, enjoyed special facilities for co-operation with the Air Ministry and set themselves to tackle the problem of how best to secure the photographs wanted for the mapping of new countries at small scales. Even since the date of their field work new equipment (sights, etc.) have appeared. But the value of their work is not thereby diminished. If Civil firms design special aircraft for the purpose there is much to think over in the chapter on Equipment and Detailed Procedure. The instruments used in the experiments and their performances are carefully described and above all a really practical routine in the air has been evolved. This or that pilot may no doubt have found, by experience, methods peculiarly suited to himself and differing from those here advocated, but if so, they have, so far, been inarticulate and not even the most skilled can fail to profit by a study of this book.

To the surveyor the most interesting chapter will be that on mapping by navigation and oblique photographs. Canada maps from obliques but in her case photographs are used singly and the perspective grid employed allows the draughtsman to copy the detail direct on to the map. Obviously this system postulates flat country. The authors on the other hand use each oblique photograph as evidence of angular measurement only. The interesting grid they describe is azimuthal in character and is designed to record horizontal and vertical angles. The plotting is done from pairs. Elsewhere in the book there is little or nothing on contouring except in very approximate fashion, and to the surveyor this is a most important omission. Contours, however, rough, are an indis-

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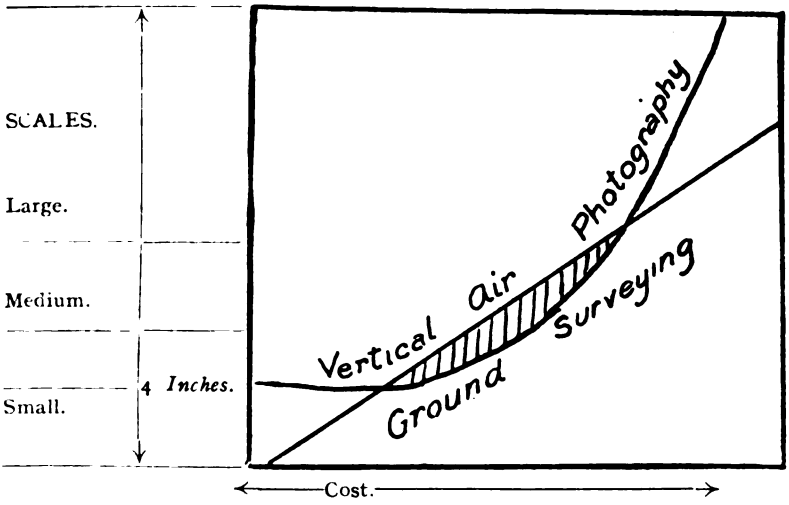
pensable feature of maps which may be used for development. The first investigation of a railway project, for example, demands them.

We should have liked to have seen some mention of that co-operation between ground and air topography, which must sooner or later, obtain. In no very large area will air photography serve all purposes, and yet in all areas it would help. In the future one would like to see airmen attached to large surveys so that the really difficult places could be photographed and not the easy ones, and that quick transport and supply could serve the ground parties. Indeed, Canada has already found how invaluable reconnaissance from the air, and the transport of survey parties by the same means can be, especially during a naturally short field season.

Dominion and colonial surveyors will be interested in the question of costs. The authors quote no actual figures, but their conclusions, in terms of flying time, number of exposures, etc., will be valuable in framing estimates.

Naturally, confined as it is to small scale method, the book says little about the influence of scale on cost and little has appeared elsewhere in print. It is, however, an interesting point. The cost of ground surveying varies roughly in proportion to scale and not to area on paper, because the surveyor does not map the same amount of detail on a small as on a large scale, and visits fewer places. His expenses mount then more or less in a straight line if we show them on a graph. "Vertical" photography is, however, an area question and its expenses mount in a curve. Photography is not practicable at scales smaller than two inches to the mile, and a photograph may be enlarged to about double the scale for mapping. These facts mean that the relative expenses will mount, with increasing scale, something after the pattern of the figure, and that photography will be as cheap for a four inch map as for a half inch.



The best economic chance for vertical photography is bound, therefore, to lie somewhere in the medium scales however large or small the shaded area may be under any given circumstances.

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R.L.B.

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The index, which by the way is at the beginning, might be expanded with advantage and the subject matter of the first part would be simpler to refer to if arranged on a more logical plan. These minor weaknesses will no doubt be rectified in future editions.

The detail of tests is good and among the other subjects dealt with are floors, roads, tennis-courts, sewers and cottages.

A.M.

REINFORCED CONCRETE DESIGN.

VOLUME I, THEORY.

By OSCAR FABER, O.B.E., D.SC., M.INST.C.E., A.C.G.I., etc., and P. G. BOWIE, A.C.G.I., A.M.INST.C.E. Price 14/-.

VOLUME II, PRACTICE.

By OSCAR FABER. (Edwin Arnold and Co.) Price 18/-.

THESE two volumes are mainly devoted to the design of beams and columns of reinforced concrete, and the subject is very fully treated.

The mathematics involved are unavoidably ponderous from the very nature of the subject, but wherever possible they have been banished to appendices ; while in all cases a clearly understandable result is produced in the form of a simple table or graph, which can be easily handled by the practical engineer when he comes to design his structure. Plenty of numerical examples are given ; and the fact that the symbols used are nearly all identical with those to which one is accustomed saves a vast amount of mental effort.

BEAMS. Simple bending is first dealt with. The authors consider that the formulæ generally recommended for T beams and doubly reinforced rectangular beams are too complicated, and show how close approximations can be made by simpler methods.

Beams continuous over two or more spans are then considered in great detail. The various bending moments produced by different conditions of loading, such as all spans loaded, alternate spans loaded, etc., with uniform, central, two point, and triangular loads are worked out for varying proportions of the weight of the external load to the weight of the structure itself, and shown graphically. Comparing these results with those obtained by the usual " ends fixed and half-fixed " approximations, it would appear that the latter is quite good enough for simple structures ; except that a small percentage of negative reinforcement over the centre portion of each span should be provided to allow for the possibility of very uneven loading.

In the above the stiffness of the supporting concrete columns is neglected. This assumption is on the safe side ; except at the ends of the beam when the outside columns are monolithic with it, and this case is separately treated.

A study of moments in beams, allowing for the stiffness of all supporting columns, is also given. As regards this latter the authors give it as their opinion that " only the most skilful and experienced engineers should consider this treatment—for all others it is too dangerous. Even for them t is too cumbersome for general use in practice, except in special cases."

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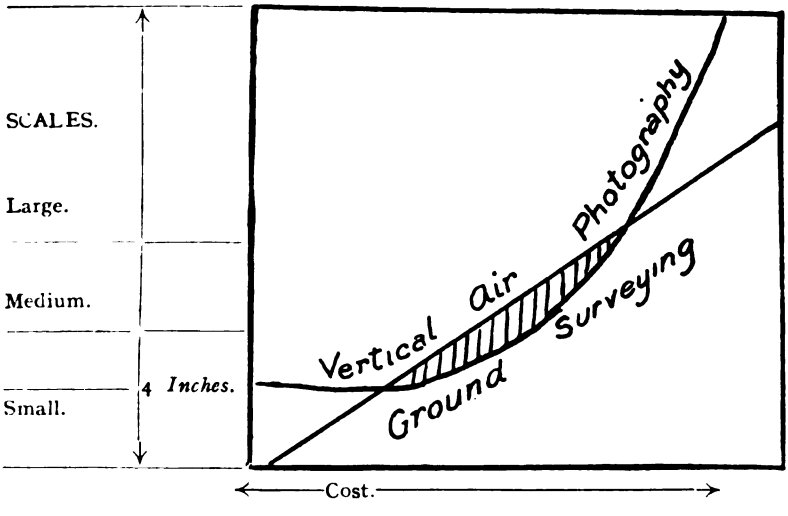
We should have liked to have seen some mention of that co-operation between ground and air topography, which must sooner or later, obtain. In no very large area will air photography serve all purposes, and yet in all areas it would help. In the future one would like to see airmen attached to large surveys so that the really difficult places could be photographed and not the easy ones, and that quick transport and supply could serve the ground parties. Indeed, Canada has already found how invaluable reconnaissance from the air, and the transport of survey parties by the same means can be, especially during a naturally short field season.

Dominion and colonial surveyors will be interested in the question of costs. The authors quote no actual figures, but their conclusions, in terms of flying time, number of exposures, etc., will be valuable in framing estimates.

Naturally, confined as it is to small scale method, the book says little about the influence of scale on cost and little has appeared elsewhere in print. It is, however, an interesting point. The cost of ground surveying varies roughly in proportion to scale and not to area on paper, because the surveyor does not map the same amount of detail on a small as on a large scale, and visits fewer places. His expenses mount then more or less in a straight line if we show them on a graph. "Vertical" photography is, however, an area question and its expenses mount in a curve. Photography is not practicable at scales smaller than two inches to the mile, and a photograph may be enlarged to about double the scale for mapping. These facts mean that the relative expenses will mount, with increasing scale, something after the pattern of the figure, and that photography will be as cheap for a four inch map as for a half inch.



The best economic chance for vertical photography is bound, therefore, to lie somewhere in the medium scales however large or small the shaded area may be under any given circumstances.

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and have not the access to old papers and books are enabled to see the development of the game from its commencement as a Corps institution.

The book will bring back to the older generations many recollections of happy days connected with R.E. cricket, and to the younger generations it will show the high standard that was reached in the past, and be an incentive for them, not only to maintain R.E. cricket at the same high level, but to go one better and improve it.

Your reviewer remembers, when he was a Y.O. at the S.M.E., the encouragement that was given to Corps games by the Commandant, Sir T. L. Gallwey, and his Brigade Major, Major Marindin, was very helpful, and there is no doubt an officer good at games is good also at his work. I am sure R.E. Games owe a great deal to this help from their commandants.

Before the ground was enclosed every hit was run out, until many a real good bat has got himself out, by his wish to get a tenner or a figure approaching that, and utterly exhausted from his exertions, has fallen a victim directly afterwards. The distinguished Adjutant General to the forces in France in the last war was one who saved scores of runs by his energy, pace and throwing powers down the hill towards the New Brompton Road.

Some unselfish and important members of the team whose fame and names are omitted from the book are those who were told off to entertain our guests when more important members slipped off to bed. Many a good bat has shortened his cricket career the next morning from that last game of Hi-cock-a-lorum jig-jig-jig, and his entertainer who fell on top of him the last night fell metaphorically beside him next day. These omissions must be overlooked when we think of the care and pains taken in the collection of the mass of information in the book. All the essentials are there and it will give great pleasure to those who knew Renny, L. K. Scott, Jim Fellowes, Hedley and other giants to read again and again of what they did—and to those who only know them by reputation to read of what they did for Corps cricket. Your reviewer is sure that all R.E.'s will heartily thank Capt. Rait Kerr for "A History of R.E. Cricket," and we certainly owe him a debt of gratitude for what must have cost him many hours of hard work for the honour of Corps cricket. It is also satisfactory to know it was written by an R.E. cricketer who made his century against the Gunners.

C. WINGFIELD-STRATFORD.

AT THE CAPTAIN'S TABLE.

By C. W. DAVY (Simpkin, Marshall). Price 6/-.

MOST of us at one time or another have experienced the hospitality of the Captain's Table and have been grateful to it for relieving the monotony of a voyage. Like the real thing, in Colonel Davy's imaginary voyage the flow of a conversation contains both excellent fooling and serious discussion, while the voyage itself is not wanting in some exciting incidents. Altogether the book may be recommended as a suitable companion for some hours of idleness in the holiday season.

F.E.G.S.

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MAGAZINES.

REVUE MILITAIRE FRANCAISE.

(*March*, 1925.)—*The Motorization of the Army.* By this expression General Camon means the replacement of the horse by the internal combustion engine, a process which he recognises as inevitable to meet modern war conditions. The vehicles required in the army are the lorry moving on wheels on roads, and the tractor capable of moving across country. Sufficient of the former are obtainable in the open market ; the latter are not so common, and on these the writer concentrates, discussing the types now manufactured in France, their qualities and defects, and arriving at the conclusion that the Latil agricultural tractor could readily be adapted to military needs and save specialization and consequent high cost of production. (*To be continued.*)

Dogma or Opportunism. Capt. de Gaulle in this article utters a warning against the French predilection for absolute and concrete systems of warfare, deducing from history the manner in which this peculiarity has already led military opinion astray. The victories of Frederick II led French officers to believe that heavy fire was the secret of success ; hence it was only necessary in every case to place in line the greatest possible number of rifles and guns. Fortunately the great military chiefs of the Revolution cut themselves adrift from dogma. Napoleon excelled in adapting his plans to existing circumstances, the condition of the enemy, the ground, distances, the personalities of his commanders, the state of his troops. From the date of his defeat in 1815 for forty years conditions in France were unfavourable to military progress. In 1855 and 1859 the Crimean and Italian wars were taken to prove the invincibility of infantry fire ; immediately after this the issue of the *chassepot* and machine gun to the French troops appeared to confer on them a marked superiority of armament, so that in 1870 it was considered only necessary to hold a prepared position from which powerful long range fire could be developed. Deducing by degrees that the German victory in this war was partly due to French passivity, carried so far that they refrained from attacking even to take advantage of openings which German rashness had placed in their way, the new *Infantry Regulations* of 1875, and even those of 1896, advanced to the other extreme ; it was only necessary to attack the enemy whenever and wherever he was met to ensure victory, a doctrine which still held good at the opening of the World War. Napoleon's careful study of the special circumstances obtaining as he undertook each campaign was forgotten ; fire effect was a secondary consideration ; it caused delay in getting to grips with the enemy, and field fortification was absolutely neglected. The grave objections to this doctrine which had been advanced by Col. Pétain and others were brushed on one side. Tactically the fallacy of the doctrine was proved during the frontier battles at the opening of the war, strategically in faults in the concentration, and neglect of the fortresses in the North of France. The victory of the Marne showed a return to saner principles, but the lesson was not finally assimilated until after the disastrous opening of the 1917 campaign,

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and only applied consistently from the summer of that year. The *"Réglement sur la conduite des grandes unités"* is based on sound principles, and refrains even from suggesting any general rule of action, but theories and abstractions are again raising their heads, and require drastic pruning.

Concerning a German Opinion. Chapter II of the article by Col. Alléhaut and Major Goubernard, dealing with artillery matters. (A.) General von Taysen states that the French Army is well supplied with artillery, that heavy to light guns are in the proportion of 1 to 1.2, yet many are not satisfied, claiming a proportion of gunners to infantry of 1 to 1. This is true, but no one suggests that all these guns should be integral parts of the division; the latter would be overloaded in the ordinary way, but there are many occasions when the divisional artillery requires to be supplemented temporarily. The divisional artillery is now probably sufficient for open warfare, at any rate, when the infantry can advance after the initial engagement, but certainly a proportion of gunners to infantry of 1 to 1 could only be obtained at the expense of infantry, and would be a national danger. (B.) The General remarks adversely on the centralization of the artillery command in the army corps and division. With this criticism the writers are inclined to agree. No doubt the concentrated effect of massed artillery is decisive in the opening stages of a pitched battle, but later on it is the infantry who carry on the fight. They require support here, there and everywhere, and for this to be opportune and take the enemy by surprise, decentralization, at any rate for the time being, is essential. (C.) There is no subordination of the artillery to the infantry. This, again, the writers think a fair criticism; it raises a very thorny question, but is not quite so serious as the German contends. Out of the mass of artillery certain batteries are always told off for the direct support of the infantry, which the regulations say should act "either in accordance with the pre-arranged plan, or following the demands of the infantry which must be satisfied at every stage of the battle." But is this sufficient? Assuming that the infantry commander is lucky enough to get a message through to his supporting battery so far to the rear, will the battery commander infringe the orders of his time-table to satisfy a request of the infantry? The French regulations should make more definite the subordination of the supporting artillery to the infantry, and this point is argued at length. Even the accompanying artillery, when a suitable weapon shall have been invented, cannot afford all the benefit that can be obtained from the more powerful guns. These guns should be separated from the mass of the artillery to follow their infantry units more closely, so as to facilitate rapid communication with them. This arrangement need only be temporary; if the whole line is held up these guns would be recalled to the divisional mass to help to batter another opening into which the infantry can enter. (D.) Unreasonable demands from the infantry for a special artillery weapon. Certainly a demand is made for guns to accompany the infantry closely; the Germans have felt the same want and have adopted the heroic remedy of detaching field guns for the purpose. (*To be continued.*)

An Encounter Battle. Virton. Commandant Grasset's article is continued, and traces the action of the 8th Division up to 10 a.m., by

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which time it was fully deployed. Accompanied by a sketch showing the general situation at 10 a.m. (*To be continued.*)

The Decline of the German Effectives in 1918. The continuation of Lt.-Col. Paquet's article, dealing with the German offensive on the Aisne (27th May) and showing that the density of their troops was considerably less than it had been in March. (*To be continued.*)

Powders and Explosives. By Squadron Commander Duchemin. By powders is meant explosives which are comparatively slow acting, and are used as propellants, such as the French *poudre B.*; by explosives those which are instantaneous in their action. A short description of the difficulties experienced in France at the outset of the War in meeting demands for explosives, and of the remedies applied, with remarks on various nitro-compounds and on the raw materials used in their manufacture. (*To be continued.*)

(*April*, 1925.)—*The Motorization of the Army.* The conclusion of the article by General Camon. His main idea is to encourage the use by agriculture and commerce in times of peace of such vehicles as might be readily adapted in time of war to warlike ends. Excepting certain special vehicles and such ordinary ones as may be required by the army in peace time for the covering troops and for training, all others will be obtained by requisition on the outbreak of war and will consist of agricultural tractors, and taxis, delivery vans and lorries. Of the last three the chassis only will be of use to carry guns, and for the guns special mountings will be required. A chapter is devoted to the supply of petrol and other fuels. The whole matter requires to be worked out in detail by the General Staff in consultation with the Ministers of Commerce and Agriculture.

The British Empire in 1924. By Commandant Texier. An analysis of the effect on the land, air, and sea forces of Great Britain of the advent to office in 1924 of a Labour Government. The writer has not, however, mentioned the fact that Labour, although in office, was not in power. This month the mother country only has been dealt with, the imperial policy of Labour is to follow. (*To be continued.*)

Concerning a German Opinion. Chapter III of the article by Col. Alléhaut and Commandant Goubernard dealing with cavalry and tanks. The former is dismissed with a few lines, the German General's remarks being in the main true. Tanks, *i.e.*, the French *Renault*, are discussed at great length. The General remarks that the French possess more tanks than any other nation, whereas his opinion, backed by that of many other Germans, is that in future wars tanks will prove to be of comparatively negligible value. He allows their stimulating effect on their own infantry, but states that therein lies a danger, for troops accustomed to them will hardly attack boldly without them. He quotes statements from the French press and books in support of this contention, and continues that, granted the development of anti-tank defence, the destruction of the tanks would have a moral effect opposite to that expected. The authors then summarize the defects charged against the *Renault* tank, and claim that these are to a great extent exaggerated. The article should be read in the original. (*To be continued.*)

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An Encounter Battle.—Virton. Commandant Grasset continues his account of this battle from 10 a.m. to 12 noon, and a sketch is attached showing the general situation at the latter hour. During this period more troops on each side entered the battle, and the French Artillery was making its pressure felt. The German front line troops had halted and firmly entrenched themselves; the French had made little or no use of the spade and were eager to advance but checked by the Germans' superior artillery. (*To be continued.*)

Anti-Aircraft Fire and Defence. The continuation of Col. Pagézy's article. In Chapter III the writer summarizes the characteristics of A.A. guns, and the limitations of the existing models. Their moral effect on the enemy aircraft is very great; at the same time they are themselves very vulnerable, principally owing to the large numbers of trained men required to work them and all the observing and calculating machines involved; a single casualty in the detachment is difficult to replace. A section is devoted to what is named the "volume of action," *i.e.*, the height, range and horizontal angle within which the fire of a gun is effective; another to the mobility of different mountings, such as the *auto-canon*, the gun carried on a trailer, and platform models. Chapter IV is devoted to considerations governing dispositions for the defence of a forward area, including the protection of observation balloons. (*To be continued.*)

A German Controversy. By Commandant H. Martin. The *Reichsarchiv* recently published the first two volumes of "Der Weltkrieg 1914-1918." The authors not only record facts, but comment on them and give their opinions, localizing mistakes and fixing the responsibility for them. Some of their decisions have already aroused controversy, such as General Wetzell's article in *Wissen and Wehr* No. 1 of 1925, defending Moltke in part and Bülow entirely from the accusations of the *Reichsarchiv*.

Books and Reviews. La Bataille de Flandres. By Col. René Tournés and Capt. H. Berthemet (C. Lavanzelle et Cie.). Published under the direction of the Army General Staff. The great interest of this book is due to the fact that all the German 4th Army records of this battle from 9th to 30th April, 1918, were captured, and from them it has been possible to reconstruct events "in the atmosphere of the German High Command," and compare them with the measures being adopted by the French at the same hours and dates.

La Turquie, l'Allemagne et l'Europe depuis le traité de Berlin jusqu'à la guerre mondiale. By Gen. M. Moukhtar Pasha (Berger-Levrault.) A half century of Turkish political history by a man who played a considerable part in the late Ottoman Empire. Minister of Marine in 1910, and commanding the Turkish 2nd Army in 1912, he was the defender of the Chatalja lines, and was Turkish Ambassador to Berlin during the World War. He clearly explains Turkey's decision to range herself on the side of the Central Powers against the Entente.

May, 1925.—French and German Fortifications. By R. Normand, Col. of Engineers. A short outline of the fortress systems on the French and German frontiers, sketching their history and the objects for which they were constructed and modified from time to time. Generally speaking in their first conception, those of the French were intended for defence

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and to cover the mobilization of their armies, those of the Germans to facilitate invasion of the adjoining countries. Latterly criticism of the French purely defensive system invoked reconsideration of the scheme, but little was done, while the Germans, no doubt in preparation for an attack on France through Belgium, during the years immediately preceeding the late war, spent large sums on the fortresses facing France, openly adapting them for the defence of Alsace and Lorraine, and for limiting the possible avenues of approach thereto from France, in fact, adopting the system already developed on the French side. Defects in the German system are pointed out, and the article is accompanied by a sketch map—scale about 35 miles to the inch. (*To be continued.*)

Concerning a German Opinion. The continuation of the article by Col. Alléhaut and Major Goubernard, arguing that the tank is really an infantry weapon, and that the infantry would be serving their own best interests in protecting it and favouring its advances in every way they can. Protection of the tank by artillery, even by the guns detached from the divisional artillery for direct support of the infantry, is impossible in practice. In short, full protection for the tank against anti-tank weapons unexpectedly brought into action will only be attained when the infantry shall have their own accompanying guns, weapons not yet realized. Still, the *Renault* tank, if more is not demanded of it than it can conceivably perform, is not to be despised.

Chap. IV. *Aviation* is only treated briefly by Von Taysen. He exaggerates certain expressions in the French regulations and individual opinions expressed in magazine articles to bolster up his theory that, in this field as in all others, French military ideas tend to sacrifice moral to material superiority. In Chap. V.—*Infantry*—the authors first give a summary of Gen. von Taysen's arguments, and in Part II their own comments. Briefly, von Taysen accuses the French of having made a dogma of the necessity for fire superiority on the side of the attack, of subordinating their infantry to the material arms—artillery, tanks, aviation—of diminishing their infantry effectives for the benefit of the other arms, and of degrading them from the rank of principal arm. This dogma kills the spirit of the infantry. But even if the French regulations do insist upon the necessity for superiority of fire in the attack, it is a principle universally admitted; the Germans themselves go so far as to contemplate the temporary attachment of guns to companies, and of *minenwerfer* to sections and even to combat groups. As regards the rest of his points it is possible that French ideas are not entirely free from mistakes, and by meditating on them it should be possible to arrive at just conclusions. (*To be continued.*)

An Encounter Battle.—Virton. Commandant Grasset's article now follows from 10 a.m. to noon the fortunes of the 3rd Division of the 2nd Corps, which was on the left of the 8th Division, and afterwards reverts to events near Virton from noon to 18.00 hours. Early in the afternoon General Boëlle (4th Corps) decided to retire the 8th Division slightly and occupy a position south and south-west of Virton, which was fairly well organised by 15.00 hours. A map gives the positions of the troops at that hour. Endeavours were also made to open up communication

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with the 7th Division on the right of the 8th, which was found to be heavily engaged near Ethe, and from which the first news only reached the Corps Commander about 12.30 hours. At 18.30 the battle died down for the day, and orders were issued as to the line to be held by the two divisions for resumption of the battle next day. (*To be continued.*)

The German Command and Tanks during the War. By Capt. Perré. After a brief sketch of the production and employment of tanks by France, England and Germany during the War, the writer investigates the reasons for the extraordinary inferiority in numbers and design of the German tanks. This he attributes to three causes: the initial delay in ordering them, the indecision of the high command as to their value, and the decrease of industrial efficiency in Germany; the second being the most important and reacting on the other two. The first would not have occurred if the command had insisted on having tanks, and had organised industry to that end; industrial weakness would have been less felt if manufacture had been seriously commenced at an earlier date. The German High Command failed by underestimating the physical value of tanks while to some extent appreciating their moral effect, which, however, it considered could be overcome by accustoming the infantry to their presence, and by destroying them by artillery fire. Its interpretation of the experiences of the Allies was entirely erroneous; a failure in the effect was attributed to inherent defects in the tank, success to a combination of circumstances favourable to them, such as fog, smoke screens, or the fatigue of the German troops.

Anti-Aircraft Fire and Defence. The conclusion of Col. Pagézy's article. Chap. V. considers the defence of the "*Arrière-front*" and of the interior of the country, the former of which may be attacked by day or night, the latter usually only by night. The scheme of defence must be based on three considerations, which are dealt with separately: (1) What it is practicable for the enemy's machines to attempt, (2) the apparatus available for active and passive defence, and (3) the employment of these. Chap. VI deals with the French methods of organisation and command.

Propellants and High Explosives. Commandant Duchemin's article is continued, dealing this month with the production of the commoner high explosives, melinite, tolite, cresylite, and describing the apparatus required, the sources of raw materials, and substitutes, such as ammonal, schneiderite and chlorates. A section is devoted to shell filling. (*To be continued.*)

Foreign Military News. A German Controversy. The *Militar Wochenblatt* for 15th March, 1925, publishes a protest by General Borries against General Wetzell's defence of von Bülow and Moltke (*see R.M.F.*, April, 1925). Short military histories are published of General Richard von Berendt (Artillery), of General Ritter von Möhl, and Lt.-General von Taysen (Infantry).

Books and Reviews.—Mobilization industrielle. By Col. Reboul (Berger-Levrault). A history of the industrial mobilization in France during the War, 1914-18.

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REVUE DU GÉNIE MILITAIRE.

(*April*, 1925.)—*Application of Graphs to Reinforced Concrete Calculations.* This article gives graphical representations of the formulæ employed in the calculations for reinforced concrete construction and shows how these graphs can be used to shorten the time spent in checking the details of a construction project. By the use of graphs the work is not only very rapid, but is extremely simple.

Collapsible Panels to ensure the Safety of Horses in Case of Fire. A description of a method for releasing horses from stables in a fire. The panels which form the side of the stable, together with the mangers, collapse outwards, leaving the horse an exit straight in front of him. The panels are released by an arrangement of steel wire rope, which is worked from some distance away from the building. A lever is used for operating the rope and a pull on this lever causes the fall of all the panels with their mangers and at the same time releases all the horses tied to them.

A Type of Roof for Buildings which appears Suitable for the Sahara. In view of the opening up of new routes across the Sahara by means of motor cars the type of building suitable for erection along these routes, where material and labour are scarce, is considered. The one-storey house is simple to erect with the materials at hand (clay, stone and sand), but the lack of wood and steel presents a problem in connection with the construction of the roof. The article describes a method of making spherical and other types of roof with the material available.

Notes on a Detail of Construction in the Roman Arenas at Arles and Nimes.—Discusses the use of dressed stones as lintels, drawing conclusions from the effect of time on the Roman Arenas at Nimes and Arles. The Romans made their lintels too weak and nearly all are broken, but the lintels at Arles, which are placed wrongly bedded, that is, with the plane of stratification running vertically and parallel to the main axis of the lintel, appear to have resisted better than those at Nimes, where the stones are placed flat. The general failure shows that the Romans would have been better advised to support the springing of the arches of the upper gallery with arches instead of lintels, as in the Coliseum.

A Compass for Trisecting Angles. Describes a type of compass designed to trisect an angle and explains the principle and method of use.

Construction. An improvement to mangers, consisting of the addition of two iron bars is described, these bars prevent the horse from stealing from his neighbour and diminish the waste of oats due to the shaking of the horse's head in his manger when he first gets his fed.

The bars are placed across the elliptical manger and are about 14 inches apart.

A Field Exercise of the "Cadre" of the 9th Regiment of Engineers with Troops and Actual Works. This article gives a description of a scheme carried out by the "cadres" and regimental units of the 9th Engineers. Night crossings in boats, pontoon bridging, and cut rafts and engineer reconnaissance were included in the exercise, which conformed with

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a tactical scheme. The exercise took place across the Moselle near Gravelotte.

Applied Science—The Andrean Motor. This is a new type of I.C. motor designed to obtain better power by altering the length of the stroke of the piston during the four strokes. The device used to achieve this result consists of a connecting rod attached at the big end to two arms, these arms are themselves eccentrically pinned to two wheels and in consequence the end of the connecting rod follows a curve giving the piston an unequal stroke. The design gives a long explosion and a full length exhaust stroke with a short inlet and compression stroke. The advantages claimed are :—

(1) Greater utilisation of energy.

(2) Less wear.

(3) Less back pressure during the exhaust.

Complete scavenging is obtained and the weakening of the mixture with burnt gas is avoided. A single cylinder model has been tried with great economy in consumption of spirit.

(*May*, 1925.)—*The Exploitation of Quarries by the Roads Service of the VII. Army.* By Chef de bataillon du Génie de réserve Verrière. The first and second parts of a description of the supply of the road-making materials required by the VII. Army on the front from Raon l'Étape to Switzerland. The upkeep of roads is of paramount importance in stationary warfare, and the exploitation of quarries must always be one of the first considerations in their maintenance. In spite of the improved methods of road making with concrete, etc., special roads will only be justified in a few cases and the large majority of roads in war, as in peace, will be made of water-bound macadam. Whatever type of road surface is used, however, stone is still the primary material. In the case of a water-bound macadam road the cost of the stone is alleged to be 70 per cent. to 80 per cent. of the total expenses.

In war, when there is a shortage of labour, the provision of machinery for quarries is important, but the installation of large plant is limited by transport difficulties, and the writer considers that it will probably not be economical to serve a large area from one quarry. The useful radius of influence of a quarry is limited to 30 to 45 miles, and, therefore, the writer considers that the maximum output of a quarry should rarely be more than 100 or 150 tons a day.

One machine which the lack of labour renders very desirable is the stone-crusher.

In the case of the VII. Army up to the beginning of 1917, the upkeep of roads was under two Directorates ; it was then taken over by a special Army Road Service. During 1917 the service developed considerably and became a very large corps. The labour available was of very different kinds, ranging from skilled engineer pioneer companies to Chinese labour. It was found convenient to form a new unit consisting of squads, each of which was constituted of men of the same trade and commanded by a master-tradesman, and in command of this company was a captain who possessed a wide technical knowledge. This arrangement proved

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very satisfactory in the road service, and was well suited to quarry exploitation.

In choosing the quarries which should be exploited, the study of communications is as important as the examination of the geological map; it is essential that a large quarry should be near a normal gauge railway, for trans-shipments must be avoided.

The writer finishes this first contribution with a description of various types of stone-crusher, he proposes in the third part to describe the general organisation of a particular quarry, and in the last part the cost of transport from the quarries and the method of organising the labour.

Crossing of the Rhine by the Allies in 1814. By Colonel Normand. A description and criticism of the strategical movements of the Allies in 1814. The difficulty experienced by the Allied engineers in making a pontoon and boat bridge across the Rhine at Caub is explained in some detail.

The Organisation of Ground for Machine Gun Fire. By Capitaine Caminade. The article points out that this subject is not merely of interest to the infantry and machine gunners, but is also of great importance to sappers, on whom will devolve the responsibility of tracing the second line, and very often the front line also, in collaboration with the infantry concerned.

The rôle assigned to the machine guns is distant flanking fire on obstacles, etc., and barrage fire, the smaller rapid firing weapons dealing with the close support of obstacles. To enable the best use to be made of the M.G.'s in hilly country and to enable officers, who have not had practical experience of machine gun fire to site the guns in the most suitable positions, the article gives a formula for calculating the depth of the effective zone and the number of shots per minute covering this zone. By this means the number of machine guns required can be calculated. The only mathematics required is the addition of numbers taken from a graph.

The Rotor Ship. By Chef de bataillon Barré. A description of the theory of the Magnus effect.

Reviews.—The German 420 *cm. shells and the Fortifications of Russia.* By Colonel Jastrzebski. The author points out that the Russian Staff had kept in touch with the progress of German artillery and that the Russian Military Academy in 1912 taught that for permanent fortifications there should be 6 m. of concrete resting on steel beams, this thickness would resist two superimposed 420 cm. shells. An extract from a previous article by Pejcz describing the fortifications of Grodno, which were reorganised in 1912, is given as an example of work actually done.

Intensive Light, Lighthouses and Searchlights. By Ed. Marcotte. This book discusses the means of producing and propagating light and their application to searchlights, lighthouses, light-buoys and aerial lighthouses.

June, 1925.—*Quarry Exploitation* (continued). Chef de bataillon Verrière, Engineer-in-Chief, Ponts et Chaussées. The author describes various types of stone-crusher, pointing out that more motive power is

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always required than is specified by the makers, while it is generally convenient to drive the cylinders used for grading the stone from the same prime mover. The design and method of using stone crushers is described, with tables giving particulars of the work done at the quarries used by the VII Army. Similar information is given with regard to the sifting and sorting of the crushed stone. The third part deals with the general organisation of a quarry, discussing the layout, various methods of loading, transport, disposal of spoil, etc. The reviewer does not know of any similar information elsewhere and is of opinion that this article is well worth study by any officers who are likely to be called upon to develop quarries.

The Lighting and Ventilation of Mine Galleries. Chef de bataillon Barré. This first article deals entirely with the lighting of mine galleries. An electric light installation is described and all the calculations are given in considerable detail (*to be continued*).

A Serious Accident which happened in Germany during a River Crossing Operation.—A copy of an extract of the report of the official enquiry, taken from the *Deutsche Tageszeitung*.

The accident took place during combined operations of the German 6th Division, which included the passage of the R. Weser by a mixed force.

A flying bridge loaded with 160 men sunk and 81 passengers were drowned. The river here is about 330 ft. wide with a 3-knot current and on the day of the accident was comparatively calm. The flying bridge used consisted of a raft designed for 175 passengers and made of 4 boats lashed together in pairs. The raft was well made and did not fail in any way, it was found intact some 6 miles down stream after the accident.

The mishap occurred during the fifth crossing when the raft, carrying 160 men, was 80 feet from the further bank; and was caused by the bad discipline of the troops on board. A sapper in one of the boats shouted to the officer in charge that water was coming in. The officer satisfying himself that it was of no importance reassured the passengers; in spite of which several men moved over to one side where a N.C.O. of sappers was examining the boat. This somewhat increased the inflow and the N.C.O ordered the infantrymen to go to the bow and stern; the order, however, was not understood and a large number of men rushed to the side of the raft nearest the bank. The raft tilted, the two boats nearest the shore were immersed, and the men on this side were tipped into the river. Many of them having their packs and their steel helmets on sank at once, but the greater number were saved by a salvage party from the bank. Meanwhile, the engineer officer, who had also fallen into the water, but had managed to reach the bank, gave the order to loose the cable, so that the raft drifted downstream. Two of the boats were water-logged and the raft had a severe list, but it still carried some 60 men who had remained on board. This officer then sent a rescue boat to take off the men remaining on the raft. A second officer (of engineers) who had remained on the raft took charge and endeavoured to make the men enter the boat singly as directed by him and without rifles or equipment. But, following one man who led with his equipment and rifle, there was a rush for the boat,

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with the result that it was capsized, while the raft was tilted to such an extent that all were thrown into the water; very few were saved.

The *Revue du Génie* draws attention to the following points which arise from this accident:—

(1) The personnel ferried across in a raft should be made up of complete units under their own officers and N.C.O.s and the instructions of the technical staff should be given to the passengers by their own officers.

(2) In this case it would probably have been better to tow the raft ashore after the first accident, rather than try to load the men on to a boat.

(3) It is expedient to provide life-belts for crossings of this kind, in spite of the delay which must be caused by the limited number of belts available.

(4) A selected rescue party well supplied with material should always be detailed.

The advantage of having a mechanically propelled boat at hand is also remarked on.

Données Numériques.—Figures are given for a road construction in mountainous and rocky country, requiring blasting and large revetments.

H.C.K.W.

BULLETIN BELGE DES SCIENCES MILITAIRES.

(1925. *Nos.* 4 *to* 6 *inclusive*).—The account of the operations of the Belgian Army during the Great War, 1914-1918, is continued, events taking place on October 6 and 7, 1914, being dealt with in the numbers of the *Bulletin* under notice. It was the question of the assistance that would be forthcoming from the Allies, and its extent, which at this time was the most important factor to be borne in mind by the Belgian High Command in connection with the plans under its consideration for the further operations of the Belgian Army. The position of affairs in the camps of the Entente Powers is, in consequence, briefly reviewed (in No. 4). At this period, the transfer of the British Army from the Aisne to the line of the Lys had just begun and two divisions of French Territorials were being transported from Havre and Paris to Dunkirk; the latter troops, together with Admiral Ronarc'h's brigade of Marine Fusiliers, had been formally promised by the French Cabinet to the Belgian Government for the purpose of relieving the situation at Antwerp. However, the French Generalissimo was entirely opposed to the idea of sending French troops into the Belgian fortress and appears to have formed the opinion that the Belgian Field Army should without further delay leave Antwerp and aim at joining up with the left of the Franco-British line as quickly as possible. The special mission assigned by Joffre to the British Army, and concurred in by its Commander, was now that of prolonging the left of the Entente line with a view to enveloping the German right and putting out a helping hand to succour the Belgians. Certain important communications were passing between the British and French authorities, but the Belgian

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High Command was, it is stated, ignorant of their tenour, nor was it aware that General Pau, who had left Paris on October 4 for the Belgian G.H.Q. was the bearer of a message which contained the suggestion that the Belgian troops when withdrawn from Antwerp should retire on Deynze and Thielt and not on Bruges and Ostend. The Belgian High Command was, however, cognisant of the measures taken for the transfer of the British Army from the Aisne to the Lille region and had also been apprised of the intention of the British Government to send the 3rd Cavalry Brigade and the 7th Division to Belgium, and that Zeebrugge and Ostend had, in view of the destination of these troops being Antwerp, been chosen as ports of disembarkation for them. The Belgian High Command expected that the "corps de secours" provided by the British and French authorities would be constituted not later than October 6; it seems to have felt, however, that this "corps" could not reach Antwerp in time to save it. The review of the situation contained in the original article discloses the fact that at this time serious differences of opinion existed in the highest quarters as to what should be done to meet the situation in Antwerp. Having learnt of the arrival on Belgian soil of the first of the reinforcements from England, King Albert summoned a meeting of the *Conseil Supérieur de la Défense Nationale* at his Palace in Antwerp and invited the British First Lord of the Admiralty to be present. The *Conseil Supérieur* met at once under the presidency of the King and its members proceeded to examine the situation, which is fully set out in the original article (in No. 5). The line of the Nèthe having already been forced by the enemy, the *Conseil Supérieur* was unanimously of opinion that the bulk of the Belgian Army should without loss of time cross to the left bank of the Scheldt with a view to making good its escape from the menaced citadel. The situation was a critical one, and it is evident that the Commanders of the British 7th Division and of the Royal Naval Division did not intend to allow their commands to be placed in such a position as would lead eventually to their being cut off by the Germans besieging Antwerp, and they regulated their movements accordingly; it is made evident in the original article that its author disapproves of the measures taken by and the conduct of the British Commanders in question. At this time, two groups of enemy troops were threatening the Belgian Army; one of them had been attempting for three days to force the passage of the Scheldt at Schoonaerde, whilst the other, being the main body of the besieging force, had already broken through the front of the 3rd Sector of Defence and was advancing through the Belgian line in the section along the Nèthe, between Forts Duffel and Broechem. In these circumstances, the Belgian High Command issued directions for the following policy to be pursued: the second, or inner, line of forts and the ramparts of 1859 were to be defended *à outrance*; the forts of the first, or outer, line still capable of resistance were to be defended as isolated works; when the second line of forts and the old ramparts became untenable their garrisons were to be withdrawn into the retrenched camp on the left bank of the river and to hold out there as long as possible. At 8 p.m. on October 6, orders were issued for the withdrawal of the main body of the Belgian Army to the left bank of the Scheldt; these orders are set out at length in the original article and provide for the movement to

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take place in three columns. These operations were carried out with complete success; the enemy being busy in carrying out bridging operations on the Nèthe and in preparing emplacements for his heavy artillery, in view of the attacks projected for the morrow, does not seem to have become aware of what was passing in the besieged fortress. The duty of defending the "second line," i.e., the inner line of forts, was assigned to General Dossin, and orders for its occupation reached him at 9 p.m. on October 6; for this purpose, there were placed at his disposal, in addition to the garrisons of the forts and redoubts, 3 Belgian mixed brigades, 3 brigades R.N.D., 2 fortress regiments, some siege artillery and an armoured train. A description of the "second line" and the steps taken in connection with its defence are given in some detail in the original article (in No. 6); the armament of the forts was no match against the German heavy artillery, and the garrisons of the forts, it is made clear, were of exceedingly poor quality. On the morning of October 7, the Germans, being ignorant of the fact that the Belgian Field Army had escaped from the fortress and was already concentrated in the *Pays de Waes*, continued in somewhat leisurely fashion the movement which had been in progress for some days for the purpose of completing the close investment of Antwerp; so weak, indeed, was the effort that the enemy was making at Schoonaerde with a view to forcing the passage of the Scheldt at this point—breadth of river here varies from 1000 to 1500 m.—that the Commander of the Belgian 4th Division was able to hold his own without calling on the 6th Division, which had been placed at his disposal, for assistance.

Among other articles of interest in the numbers of the *Bulletin* under notice are those by Lieut.-Gen. Joostens entitled *Voyage au Maroc* (in Nos. 4 to 6 incl.) and by "I.C.M." entitled *La cartographie pendant la guerre.*

W. A. J. O'M.

REVUE MILITAIRE SUISSE.

(1925. *Nos.* 1 *to* 3 *inclusive*).—The article by M. J. Fleurier entitled *Une légende. La faillite de la fortification permanent pendant la grande guerre* is continued in Nos. 2 and 3, and the operations in the neighbourhood of Antwerp are dealt with therein.

The suggestion is made that the defence of Antwerp might have been prolonged beyond the date on which the surrender was made had the British force, i.e., the R.N.D., co-operated effectively with the Belgians.

In an article entitled *Pro Jomini* (in No. 2), Colonel Lecomte takes up the cudgels on behalf of his famous compatriot, and repels with vigour the suggestion that, in view of the changed conditions of war, Jomini's writings have lost their value, as alleged by Lieut.-Col. Mayer in an article entitled *Grandeur et décadence de Jomini* which appeared in the numbers of the *Revue Militaire Française* for November and December, 1924. Colonel Lecomte agrees that the *Traité des grandes opérations* no longer contains lessons of value for the present day military student; he contends however, that other works by Jomini possess a special value at

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the present time, this being particularly so in the case of the *Précis de l'Art de la Guerre, édition* de 1894.

A description of the Swiss light automatic rifle, *Le fusil Furrer* (1924 model) is contained in No. 3 of the *Revue*.

(1925. *Nos.* 4 *to* 6 *inclusive*).—Major C. Shaffner contributes an article entitled *Le bataillon de pontonniers I et les ponts lourds* to No. 5 of the *Revue* under notice; a short history of the pontoon troops of the Swiss Army is given therein and a summary thereof may be of interest to Sappers. About 1820, the Diet voted a credit for the creation of a *train fédéral de pontons*; it was provided with sufficient equipment for the construction of a light pontoon bridge 120 m. in length. Some years later a second *train fédéral de pontons*, with an equipment identical in every way with that in possession of the first "train," was formed. A further development of the bridging troops took place in 1850, the Swiss Army being at this date endowed with a new organisation; six pontoon companies were then created, the equipment provided for them being sufficient for a light bridge (max. load 3000 kg.) 232 m. in length. The Swiss Army was again remodelled in 1874, and at the same time the engineer arm was reorganised and formed into 8 battalions, viz., one battalion per division, consisting each of a pontoon company, a company of sappers and a company of pioneers—the bridging equipment of a battalion was sufficient for a pontoon bridge 53 m. in length. About 1890, a further change was introduced, owing to the Swiss Army being re-organised on an Army Corps basis; the engineer battalions were now broken up and the pontoon companies grouped together, each of the bridging units so formed was now known as an *équipage de ponts* and consisted of 2 pontoon companies and a "train" detachment. One such *équipage* was allotted to each Army Corps and was provided with material sufficient for a pontoon bridge 132 m. in length; this organisation continued in existence for 20 years. A change was made in 1911, when the *bataillons de pontonniers*, each consisting of 3 pontoon companies and a "train" company, were formed. In 1914, when, on the outbreak of the Great War, the Swiss Army was mobilised, the first company of each battalion was split into two, each half-company—provided with material for a pontoon bridge 40 m. in length—was named an *équipage de ponts divisionnaire*, and allotted to a division. In the case of the *bataillons de pontonniers I*, the battalion staff, the 2nd and 3rd pontoon companies and the "train" company were formed into an *équipage de ponts d'armée* and placed directly under the Commander of the 1st Army Corps. In December 1917, a fourth pontoon company was allotted to each battalion and, in consequence, a complete company was then attached to each division. The original article, which is illustrated, gives a brief description of the present day bridging equipment of the Swiss Army; therein is also recorded the part played by the pontoon units attached to the 2nd Division during the manœuvres which took place in Switzerland in September, 1924.

The article by M. Jean Fleurier entitled *Une légende. La faillite de la fortification permanente pendant la grande guerre* is continued (in No. 5). In this part of the article the third phase of the operations for the capture of Antwerp is examined; the epilogue (Oct. 7 to 10) can, M. Fleurier

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says, be summed up in two short sentences; (1) the Belgian Field Army escaped from the Germans, and (2) no stand was made behind the ramparts of the entrenched camp thrown up in 1859, nevertheless, to the existence of these defences was it due that the enemy's advance was held up for 24 hours; in consequence, the greater part of the permanent garrison was able to make good its escape from the fortress and a portion of it managed to join up with the Belgian Field Army, the balance only becoming neutralised on crossing the frontier into Holland. In the original article, details are given of the troops left in the fortress after the Belgian Field Army was withdrawn therefrom, and the military situation which the Governor of Antwerp was called upon to deal with is also briefly discussed. M. Fleurier finally seeks an answer to the question: Could a more effective defence of the fortress than actually took place have been put up? An interesting examination is made of the course of events, and tables are given in which is set out the damage done to the several Belgian forts by the German artillery, the dates of construction of these forts is stated, the numbers of shell of the different calibres fired at each of them, the numbers of hits, the duration of the bombardment of each of them, the causes and dates of the evacuation or surrender of each fort and the casualties suffered by its garrison being also recorded in a concise and clear form. It would appear that M. Fleurier is of opinion that false hopes were raised at the Headquarters of the Belgian Army as to the assistance which would be given by the British in connection with the defence of Antwerp; the final conclusion at which he arrives is that the reason why the defence of the principal line broke down so quickly was due not so much to the defects in the fortifications and the armament of the place as to the poor quality of the troops told off to hold the fortress; their *morale* was not of the quality which enables troops to fight to a finish. For this reason, so far as the siege of Antwerp is concerned, it is a *leçon morale*, says M. Fleurier, rather than a *leçon technique* which is to be learnt from the study of the operations in connection with the defence of Belgium's citadel in 1914.

Among other articles of interest in the numbers of the *Revue* under notice are two relating to defence against aircraft; one by Lieut. Vaucher entitled *Artillerie contre avion* (in No. 5), and another by M. R. A. Jaques entitled *La défense contre avions* (in No. 6).

W. A. J. O'M.

HEERESTECHNIK.

(*April, May and June Numbers.*)

THE motor engineer will be the most interested reader of these numbers. The articles which deal with this subject are as follows:—

The tasks in front of the German Motor Industry.

The Problem of the Multi-Axle drive.

The "Servo" Brake.

The three-cylinder double action motor.

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The improvement of the explosive mixture by an automatic air inlet and by the heating of the mixture.

Spray or compressor motors.

The articles quoted above all deal with points of construction, and the following articles deal with the use of the vehicles :—

(i) Dr. Teubner describes the activities of lorries in supplying the Occupied Territories on the Rhine during the French control of the railways. Very efficient systems would appear to have been inaugurated for supplying foodstuffs, milk, coal, etc., and the moral is drawn that the existing railway system could and should be considerably amplified by auxiliary motor systems in peace.

(ii) The mechanicalization of the modern Army. This is a lengthy summary of Colonel Fuller's lecture to the Royal United Service Institution—a lecture which meets with the reviewer's warmest approbation

In the April number, in addition to its motor construction details, there is a short article on Primary and Secondary Cells and Accumulators. It is one of those short, descriptive articles meant for the education of all arms in the principles and instruments of the technical services. There is nothing of particular interest for the English reader.

In the May number, an unsigned article giving an extract from a letter from one of the Directors of Krupp's shows the amount of machinery which has been destroyed as directly serving gun manufacture, and estimates the damage at 102,000,000 gold marks.

In the same number, Mr. Baumgart has an article on the Military Map of the Future, which is taken almost direct from the *Military Engineer* of September and October, 1923. The idea of this article is that the map of the war of the future shall portray the features of the ground, not only by contours, but by a form of shadow shading. Such arguments are, of course, based on the idea of a protracted trench warfare, because in any other form of operations the reproduction of such maps with the necessary rapidity would be quite out of the question.

Major Geyer continues the discussion on Tactics and Technique, which is part of a controversy beginning with a half-hearted attack upon the General Staff for its lack of technical knowledge and sympathy. This attack was somewhat paternally reproved and the author is now explaining that he did not mean it.

Major Klingbeil, who contributes a good deal to this magazine on matters of fortification, has a short notice on Part 3.A. of the *Manual on Bridge Building*—" Heavy Bridges."

In the June number, Major Klingbeil summarises the main features of the new *Manual of Field Fortification*, Part 1, and their tactical use. He describes the subject in this way :—" Field fortification is tactics dug into the ground." German pre-war notions of defence dealt mostly with a single line, but one improved in every possible way. Distribution in depth is now established, and a great deal of emphasis is laid upon camouflage and concealment. Splinter-proof is, of course, cover against splinters of light and medium artillery. Shot-proof is proof against

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several direct hits from the 15 centimetre or single hits from a 21 centimetre; and bombproof is cover against several direct hits from a 21 centimetre and single hits from heavier calibres. Storm-proof applies to a position in which shot-proof gun positions are provided and which is guarded by sufficient obstacles to tanks. Field fortification in the attack is very much emphasised. "An infantry attack over fairly open country against an enemy equipped with modern weapons is bound to be most costly in life, even when covered by a superior artillery, without entrenching. The use of a spade lightens the approach to the enemy, makes it possible to hold what has been won against heavy counter-attack, and provides opportunities for a further attack." In moving warfare the attacker must be content with ordinary trench work. Artillery and heavy infantry weapons (trench mortars and heavy machine guns) are busy from the first in improving their cover and camouflaging themselves. Rifle and Lewis gun sections dig themselves in as soon as enemy fire prevents further advance. They dig themselves in at varying distance and in depth. Against important and fortified field positions all arms dig themselves in deeper, but after the same general pattern. Possibly under these conditions shallow communication trenches are made. In position warfare, the procedure is exactly the same, or, at any rate, follows exactly the same principles, which are that protection against enemy artillery fire is not in the strength of the actual field work, but in its distribution in depth and breadth, and in its camouflage. In the defence, this distribution is even more emphasised and camouflage made more important. The position of the infantry line of defence is labelled as comparatively unimportant with regard to field of fire, whereas the view for the field gun and the heavy machine gun is insisted upon. In certain cases where observation may be got from higher ground behind or to the flank, the infantry may even be withdrawn to the reverse side of a hill. In all cases, it is the artillery observation which is emphasised. This article is to be continued.

Mr. Heyer has an article upon Explosives in Mining Warfare, illustrated by one or two diagrams and explaining the tactics of mining in the War. There is nothing in this article of importance to English readers.

H. ST. J. L. W.

MILITARWISSENSCHAFTLICHE UND TECHNISCHE MITTEILUNGEN.

(May-June Number.)

The Question of a Decisive Victory East of the Tagliamento in October 1914. General Krauss thinks, very definitely, that such a victory could have been won as would have put the Italian Army out of action. The failure was due to the lack of definite determination and to the "sector" tactics of the war. If each Army is to go straight ahead in a pre-arranged strip how can you roll up and destroy the enemy? The Marne Battle was a case in point.

As evidence of the lack of will, he quotes H.M. Kaiser Carl, who said to him, "We shall have to prepare for that in its turn (the crossing of

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the Tagliamento). Even so we shall have got too far, for our railways cannot manage more. We simply want to get to the Tagliamento." The right wing should have been pushed forward and then swung left to push the Italians to the sea. The German group on Krauss' left (26th and 200th Divisions) got going faster, however, and over easier country. They could have, and wanted to, swing left and cut the Italians off from the Codroipo bridges. But to every request from whatever commander to exploit the victory by a " right shoulder up " the higher command objected. The will to win was not there, and the tactics were all wrong.

The Second Investment of Przemysl is continued by Major Stuckheil. The sortie of the 15th-18th December, 1914, left an unquiet front, which " stabilised " just before Christmas. During Christmas an unofficial truce gave everyone three days' quiet, and then the Garrison were called on for another sortie on the 27th and 28th. The Russians meanwhile had very considerably strengthened their defences. Altogether 18 Battalions, 2 Squadrons and 15 Batteries were told off for this sortie—but the account breaks off here.

Instruction in the Military School, by Colonel Anton Kainz, gives some very practical advice on the bearing and programme of the officer instructor (or, as he should rather be—teacher) and the analysis, partition and presentation of his subject. A short example of instruction on hand grenades is added.

Tactical Exercises; No. 1. In the last number this first tactical exercise was explained and worked out up to a certain point. It is now concluded. The exercise is worth studying.

Mountain Troops. By Colonel Schubert. This article is partly historical and partly propaganda for the mountain troops of the present day. There is nothing of importance for English military readers.

The Progressive Education of Officers of Different Armies. This point has already been discussed (in 1924) in this journal. French, Italian, Czecho-Slovakian, Roumanian and Swiss institutions are described, and it is of a certain interest to see them written up together and compared.

Artistic Smoke Screening. By Captain Fritz Heigl. In preceding numbers this subject has already been dealt with in very interesting fashion. The author now turns to the question of the smoke screening of the " home front." To awaken the proper interest in matters, the author starts by picturing England and France in the usual way as composed of men of ruthless disposition, who are systematically planning the extinction of life in Central Europe by gas, the total destruction of their cities, and the burning of crops and even of woods. Having reached the proper atmosphere, he proceeds to take as an example the city of Budweis (the capital of Southern Bohemia), and he works out very interestingly and with good illustrations how this town could best be camouflaged by smoke screening, with a view not only of hiding the town itself, but of deceiving the airmen as to its true locality. He then works out how much personnel and material he wants to carry out his

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smoke screen and bases his figures on Colonel Chédeville's article in the *Revue Militaire Française*. He does this because he considers that Czecho-Slovakia, like other countries of the Little Entente, would be persuaded in the event of war to purchase French material dating from the last war. He makes an interesting little suggestion in the course of this article as to the use by civil inhabitants of some sort of smoke-producing material, which could be thrown upon the ordinary fire or kitchener. One feels that he might have gone a little further.

The author then discusses the question of smoke-screening on river lines and other natural guides to marauding airmen. He thinks that they could be not only disguised, but apparently shifted in position by putting a thicker smoke screen along a fictitious line, whilst the river itself was screened less heavily.

Captain Fritz Heigl is full of ideas and we commend his article to those cold-blooded schemers to whom allusion has already been made.

Camouflage Painting of Field Guns. By Captain Ludwig Heindeman. The value of this article lies mainly in the good little illustrations which he gives of different types of painting employed on Austrian field guns. The subject is evidently attracting a good deal of attention, and this article will be of interest to those who deal with camouflage and with the interpretation of air photographs.

Tanks in Mountain Warfare. By Captain Fritz Heigl. It would appear that in Austria the danger of a tank attack has been discounted to some extent in view of the mountainous type of Southern Austria. The author thinks that the danger does exist and that there are few places in the Austrian Tyrol which could be reckoned immune from tanks with their astonishing powers of climbing; but he points out that defence will be the easier because the avenues of approach are much more clearly defined than in flat country and the tanks would naturally be confined, in many cases at any rate, to Indian file. Artillery should, therefore, have an easier target, whilst the construction of obstacles could be undertaken with some expectation of their being in the right place.

The performances of *Austrian ropeways* in the higher mountains are described by Colonel Edward Lacom. The article is historical rather than technical, and the ropeways proved themselves astonishingly efficient. It is stated that although the number of people who actually travelled on these ropeways runs into hundreds of thousands, there were only 13 accidents and 30 casualties. Since the War some 50 new ropeways have been constructed.

On Military Aircraft of the Present Day. Captain Hans Hännerle writes a short article on modern types, classifying them under the three factors, aero-dynamic, weight, and motor power. The discussion on aero-dynamics leads to a short discourse upon wings, and in particular those made of metal. There is a short table which gives the different motors in use, and under the heading "weight," he describes the different types of scout, reconnaissance, and bombing machines of the present day.

H. St. J. L. W.

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THE MILITARY ENGINEER.

(*May-June*, 1925.)—*The Panama Canal after Ten Years.* The early years at Panama were disappointing. The canal was opened on August 15th, 1914, and it was not until two years after the Armistice that any considerable volume of shipping was restored to the routes which it served. Tonnage during 1917, 1918, and 1919 averaged 7,000,000 tons. For 1920, 1921, and 1922 it averaged 10,000,000 tons, and then jumped to 19,000,000 tons in 1923, and to 26,000,000 tons in 1924. By way of comparison, the Suez Canal in 1924 handled 25,500,000 tons.

The capacity of the canal is limited by the locks. It is estimated that these can handle three times the present tonnage. Each lock has a width of one hundred-and-ten feet, a depth of forty feet, and usable length of a thousand feet. For commercial purposes these dimensions are ample. But it is possible that additional wide locks may be required for naval purposes. The latest American battleships have a beam of one hundred feet. It is interesting to note that H.M.S. "Hood," which passed through the canal in July, 1924, had a beam of one hundred-and-five feet two-and-a-half inches, allowing a clearance of under two feet five inches on either side.

Up to 1924, the canal did not pay its way. In that year, however, its earnings were more than twice the annual interest figure, leaving a surplus to be applied to wipe out the deficit of previous years.

The future of the canal is bound up with that of the Pacific Coast. Eighty-five per cent. of the tonnage is destined for or originates from these ports. The wealth of this territory has scarcely been tapped. The canal is destined to reap a rich harvest from the developments which will ultimately come.

The Problem of Roads in Campaigns. The author estimates the number of men needed for road maintenance under fair average weather conditions and the traffic of a Division, as a hundred men per mile. A Division would thus require some six hundred men permanently employed on road work, under service conditions. The importance of early reconnaissance and close co-operation with the General Staff during operations is emphasized.

German Crossing of the Duna River. A detailed study of General Von Hutier's crossing in April, 1917. The initial attack was carried out by three Divisions, troops being ferried across in pontoons under a smoke screen barrage. The construction of three pontoon bridges was undertaken simultaneously with the ferrying operations, one of them being for heavy traffic. At the point selected, the river was some four hundred yards in width, the current being sluggish. The whole operation was carefully rehearsed, and proved entirely successful. The writer draws the conclusion that the two principles of war—mass and surprise—are especially important in operations of this kind.

Camouflage Service in the A.E.F. No amount of artificial screening will compensate for indifference to the ordinary principles of concealment. Unless supported by strict discipline in the area in which he is working, the camoufleur can do little good. The Camouflage Service soon

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several direct hits from the 15 centimetre or single hits from a 21 centimetre; and bombproof is cover against several direct hits from a 21 centimetre and single hits from heavier calibres. Storm-proof applies to a position in which shot-proof gun positions are provided and which is guarded by sufficient obstacles to tanks. Field fortification in the attack is very much emphasised. "An infantry attack over fairly open country against an enemy equipped with modern weapons is bound to be most costly in life, even when covered by a superior artillery, without entrenching. The use of a spade lightens the approach to the enemy, makes it possible to hold what has been won against heavy counter-attack, and provides opportunities for a further attack." In moving warfare the attacker must be content with ordinary trench work. Artillery and heavy infantry weapons (trench mortars and heavy machine guns) are busy from the first in improving their cover and camouflaging themselves. Rifle and Lewis gun sections dig themselves in as soon as enemy fire prevents further advance. They dig themselves in at varying distance and in depth. Against important and fortified field positions all arms dig themselves in deeper, but after the same general pattern. Possibly under these conditions shallow communication trenches are made. In position warfare, the procedure is exactly the same, or, at any rate, follows exactly the same principles, which are that protection against enemy artillery fire is not in the strength of the actual field work, but in its distribution in depth and breadth, and in its camouflage. In the defence, this distribution is even more emphasised and camouflage made more important. The position of the infantry line of defence is labelled as comparatively unimportant with regard to field of fire, whereas the view for the field gun and the heavy machine gun is insisted upon. In certain cases where observation may be got from higher ground behind or to the flank, the infantry may even be withdrawn to the reverse side of a hill. In all cases, it is the artillery observation which is emphasised. This article is to be continued.

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MILITARWISSENSCHAFTLICHE UND TECHNISCHE MITTEILUNGEN.

(May-June Number.)

The Question of a Decisive Victory East of the Tagliamento in October 1914. General Krauss thinks, very definitely, that such a victory could have been won as would have put the Italian Army out of action. The failure was due to the lack of definite determination and to the "sector" tactics of the war. If each Army is to go straight ahead in a pre-arranged strip how can you roll up and destroy the enemy? The Marne Battle was a case in point.

As evidence of the lack of will, he quotes H.M. Kaiser Carl, who said to him, "We shall have to prepare for that in its turn (the crossing of

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the Tagliamento). Even so we shall have got too far, for our railways cannot manage more. We simply want to get to the Tagliamento." The right wing should have been pushed forward and then swung left to push the Italians to the sea. The German group on Krauss' left (26th and 200th Divisions) got going faster, however, and over easier country. They could have, and wanted to, swing left and cut the Italians off from the Codroipo bridges. But to every request from whatever commander to exploit the victory by a " right shoulder up " the higher command objected. The will to win was not there, and the tactics were all wrong.

The Second Investment of Przemysl is continued by Major Stuckheil. The sortie of the 15th-18th December, 1914, left an unquiet front, which " stabilised " just before Christmas. During Christmas an unofficial truce gave everyone three days' quiet, and then the Garrison were called on for another sortie on the 27th and 28th. The Russians meanwhile had very considerably strengthened their defences. Altogether 18 Battalions, 2 Squadrons and 15 Batteries were told off for this sortie—but the account breaks off here.

Instruction in the Military School, by Colonel Anton Kainz, gives some very practical advice on the bearing and programme of the officer instructor (or, as he should rather be—teacher) and the analysis, partition and presentation of his subject. A short example of instruction on hand grenades is added.

Tactical Exercises; No. 1. In the last number this first tactical exercise was explained and worked out up to a certain point. It is now concluded. The exercise is worth studying.

Mountain Troops. By Colonel Schubert. This article is partly historical and partly propaganda for the mountain troops of the present day. There is nothing of importance for English military readers.

The Progressive Education of Officers of Different Armies. This point has already been discussed (in 1924) in this journal. French, Italian, Czecho-Slovakian, Roumanian and Swiss institutions are described, and it is of a certain interest to see them written up together and compared.

Artistic Smoke Screening. By Captain Fritz Heigl. In preceding numbers this subject has already been dealt with in very interesting fashion. The author now turns to the question of the smoke screening of the " home front." To awaken the proper interest in matters, the author starts by picturing England and France in the usual way as composed of men of ruthless disposition, who are systematically planning the extinction of life in Central Europe by gas, the total destruction of their cities, and the burning of crops and even of woods. Having reached the proper atmosphere, he proceeds to take as an example the city of Budweis (the capital of Southern Bohemia), and he works out very interestingly and with good illustrations how this town could best be camouflaged by smoke screening, with a view not only of hiding the town itself, but of deceiving the airmen as to its true locality. He then works out how much personnel and material he wants to carry out his

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difficulty, there was no reason to suppose that a crossing of the Lower Vistula could have been easily secured in view of the lack of siege artillery, and of artillery resources of all kinds. If the supremacy of the Russian fleet in the Baltic could have been relied on, the occupation of Eastern Prussia would have facilitated landing operations. The French evidently had little faith in the usefulness of the campaign in Eastern Prussia, as even before it began they insisted on the desirability of a blow on the part of Russia towards Posen, and in compliance with this request two new armies—the 9th and 10th—were formed at Warsaw to operate against Thorn—Posen and Posen—Breslau.

The sixteen corps allotted to the Austrian front were inadequate for their task, namely, the complete defeat of the Austrian armies, and were incorrectly distributed. Long before the war it was known that the Austrian force in Galicia would concentrate in two groups, a large group facing Poland for an advance between the Vistula and the Bug (in touch with a German army advancing from Eastern Prussia) and a smaller group facing Kiev to cover the flank of the other group. The Russian distribution, however, allowed for an equal force against each group.

Plans are given showing the distribution on the whole front as actually carried out by the Russians, and what General Dobrorolski considers would have been a better distribution on the Austrian front using the same units, with the addition of the two corps of the strategic reserve and the Guard Corps (originally allotted to the First Army, but transferred to Warsaw as part of the Ninth Army). The idea briefly consists in massing 14 corps against the right and right flank of the Austrian attack, leaving an army of five corps between the Vistula and the Bug, with a strong cavalry force on the left bank of the Vistula. The rôle of this army would be to oppose an advance on the line Ivangorod—Brest Litovski by means of a strategical defence—a retreat step by step with a skilful concealment of its numerical weakness. Three strong armies composed of the remaining 14 corps would be located in the areas, Lutsk—Dubno, Starokonstantinov—Proskurov, and Proskurov—Kamenets Podolsk. Such a distribution would entail the preservation of the fortress of Ivangorod and improvement of its permanent fortifications, and the development of Brest Litovski into a large fortress of the type of Metz. The chief mass of cavalry must be grouped on the flanks whence raids could be conducted to the rear of the Austrian armies.

General Dobrorolski considers that if this plan had been adopted the Austrians could have been crushed by September 11th, the 43rd day of mobilisation; the gates into Silesia would have been opened and an advance to Berlin might have been possible.

The First and Second Armies in East Prussia might have been reduced to five corps, and four corps released to swell the armies opposing the Austrians. It would have been better to use five corps in a strategical defence on the line Kovno—Grodno than to make a useless invasion of East Prussia.

A. H. B.

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NEUE ZÜRCHER ZEITUNG.

The Paradox of the German Offensive of 1918.—The National Assembly at Weimar appointed a Committee of 28 members to investigate, *inter alia*, the causes of the German collapse in 1918, and Dr. Ludwig Herz, one of the members of this Committee, contributes an article under the above title to the *Neue Zürcher Zeitung* of July 23rd. The complete proceedings and findings of the Committee are shortly to be published, "The Causes of the German Collapse in 1918" alone occupying three large volumes. The three chief contributors to this work are: General von Kuhl, well known in Germany for his writings on military subjects, and who during the latter part of the War held the appointment of Chief of Staff to the Army Group of Crown Prince Rupprecht of Bavaria; Colonel Schwertfeger, author of a work in five volumes entitled "Belgian Documents," and who in the present work deals with the struggle between the politicians and the Army leaders; and Prof. Delbrück, the historian, whose share culminates in a bitter attack on Ludendorff as a strategist.

Reviewing the military situation, Dr. Herz asks whether the offensive of 1918 could not have been avoided. He points out that up to the end of 1917 none of the strategical hopes of the leaders of either side had been realised. The "Russian Steam-Roller" had not crushed Germany, nor had the attempted break-through on the Western Front succeeded. The entrance of Italy and Rumania into the War had not been able to bring a decision. The Americans, then beginning to arrive in Europe, relieved the strain on the British and the French, it is true, but they could hardly influence the issue before mid-summer of 1918. On the other hand, Germany's hope of over-running France and then throwing her whole might against Russia, had been shattered on the Marne. Her last card, the unrestricted U-Boat warfare was played, and known in the autumn of 1917 to have failed. Time was fighting against the Central Powers. The War map was eloquent on their side, but they were a beleaguered garrison. The failure of Russia freed Germany's back, and the troops thus released made it possible for her to dominate the situation in the West. Stegemann,* on the 16th February, 1918, gave it as his opinion that the military situation was now more favourable than ever before—indeed, that it was not only favourable in comparison with the past, but that it was absolutely favourable.

In early 1918 many patriotic Germans addressed petitions and memoranda to the leaders of the War Party, asking that if it could in any way be avoided, no great offensive should be undertaken. To one of these, however, Ludendorff replied on 22nd February, 1918, that for the first time since the invasion of France, Germany had the choice between attack and defence, and that only action could bring success.

"This cool answer," says Dr. Herz, "put the situation in too favourable a light. The German choice lay, not between attack and defence, but

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*STEGEMANN.—Stegemann was a military correspondent writing for the *Bund* during the War. His opinions, which were always pro-German, were very widely read in Switzerland and Germany, and were regarded in many quarters as almost infallible. The *Bund* is the semi-official organ of the Swiss Government, published at Berne.

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between attack and peace. The Army would endure no longer the murderous battles of position warfare. Men and materials were alike exhausted. The blockade was a strangle-hold on the country. The decision must be complete before the hordes of Americans could make themselves felt. The German General Staff had indeed won the power of taking the initiative on the Western Front, but they must note the passage of time with the same horror as before. . . . The necessity for action, then, as earlier, was forced upon Germany by her enemies. This is the first great paradox of the great offensive—that the Allies forced upon Germany an attack which she feared and wished to avoid.

"Would a break-through of the Allies' lines have brought success to Germany? Stegemann doubted whether the attacks could have progressed much farther than Amiens and Rheims. Kuhl . . . adduces many reasons for doubting whether the Army was sufficiently mobile for open warfare. But even if a break-through had crowned Germany's armies with complete success, it remains doubtful whether her enemies would have been prepared to make peace. Even if France had been removed from the list of active combatants, England would have prolonged the War; England and America would have been able to continue the economic War. They must have continued, otherwise they must have admitted defeat, political and economic, when as yet their vitality was strong, and only their Armies had been defeated in the field. This is the second great paradox of the great offensive—that the threat of it, in spite of the uncertainty as to its result, was a greater incentive to peace than its success would have been.

"This contradictory situation demanded a peace of compromise. The nations, sick of bloodshed, wanted peace. So, with few exceptions, did their leaders. But they feared, by the auto-suggestion of their own propaganda, and by offers of peace which might prove abortive, to weaken the war spirit of their peoples. As both the Anglo-Saxon races were among the combatants, a mediator was lacking. So the psychological moment was lost. Instead of a peace of compromise, without victor or vanquished, after Germany with her request for an Armistice had hoisted the white flag of surrender, came the Peace of Versailles. That has not brought the peace of the World—could not bring it, for in the words of a Frenchman, quoted by the late Lord Bertie, at one time British Ambassador to Paris, 'It contains in itself all the germs of a just and lasting war.'"

T. H. BROWN, Lieut. R.E.

THE JOURNAL OF THE SOCIETY OF ARMY HISTORICAL RESEARCH. Price 6*s*.

In the July-September, 1925, number Lt.-Col. J. H. Leslie, late R.A., the Editor, commences an article on "The Honourable The Board of Ordnance 1299-1855," and dates its "Origin" from two Conrads, father and son, who were *Attillators*, i.e., chief engineers in charge of the *ingenia*, military engines, at the Tower early in the 14th century. *Attillator*, from which the word Artillery is probably derived, is mentioned by Porter in his *History of the Corps of Royal Engineers* as a new name introduced

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at this period for the official " to whom was entrusted the repair of permanent works and also the working of the engines of war—in fact, the duties which have hitherto been shown as falling to the lot of the *Ingeniator.*" Colonel Leslie gives an interesting illustration of the *Berfrarium*, or belfry, a moveable tower used in sieges, one of the engines. He also mentions Nicholas Merbury (1414), " Master of the Works, Engines, Cannon and other kinds of Ordnance of War." The history of the Board of Ordnance should be full of interest to Royal Engineers.

Under " Questions " mention is made of some old fire locks, buff coats, bandoleers and plug bayonets which were unearthed a few years ago in the crypt of Rochester Cathedral and are now preserved there in a glass case. Two of the muskets are marked with the badge known as the Jerusalem Arms, and one is dated 1700. The buff coats have green velvet facings.

F.E.G.S.

COAST ARTILLERY JOURNAL.

(*December*, 1924).—*Development of Anti-Aircraft Artillery mentioned in the Annual Report of the Chief of Coast Artillery*, 1924. Four new types of guns and carriages are being developed, owing to the shortage of modern armament in the United States Army.

The .50 calibre machine gun has passed preliminary tests. It has a rate of 450 shots a minute.

A 37 mm. Automatic machine gun is under test, with a muzzle velocity 3000 f.s.

The 3-inch gun on fixed mount has been approved for production. Nine guns will be built in 1925 for Panama. The 3-inch gun on mobile mount has not yet passed all tests.

Difficulty of design has delayed progress in the development of the 4.7 inch gun.

The Anti-Aircraft Artillery is without any efficient apparatus for the location of aircraft at night by sound, and without a satisfactory plotting board, though a French one is being purchased for test by the Coast Artillery Board.

Smoke and Coast Artillery. An enemy must take heed of a smoke barrage because he cannot foretell what it means. A smoke curtain six hundred feet high can be dropped from an aeroplane by the emission of a mixture of titanium tetrachloride and carbon dioxide, at a speed of a mile a minute. Any combination of length, height or shape, can be obtained by using a number of aeroplanes, flying one behind the other. Poisonous gases can be sprinkled as easily as titanium tetrachloride.

Experiments carried out by Battery " A," Sixth Coast Artillery, to test the effect of battery target practice when all ranks were protected from gas by a new gas mask proved that it was suitable for use with optical instruments and only lowered the rate of fire of series of ten rounds from 2 minutes 50 seconds to 2 minutes 57 seconds. Before the gas alarm five hits were signalled, after masks were assumed four were made.

D. M. F. H.

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CORRESPONDENCE.

The Secretary, The Institution of Royal Engineers.

SIR,

With reference to the June *R.E. Journal* "Modern Scheme of Water Supply," p. 258, it is stated that sterilisation by gaseous chlorine cannot be recommended for use in a comparatively small installation, as under consideration in the essay, on account of prime cost, and need of skilled supervision. The author is apparently misinformed, as the cost of an apparatus dealing with 1,000,000 gallons per diem, manufactured by the United Water Softeners (Imperial House, Kingsway, London, W.C.2,) is £170, and that for 10,000,000 gallons £240. The cost of chlorine, allowing for transport to the tropics, would not exceed 10s. per 1,000,000 gallons. The apparatus is simple and does not need skilled supervision.

The United Water Softeners have installed at Weedon Barracks a Wallace-Tiernan Chlorinator dealing with 11,000 gallons per diem at a cost of about £170.

I enclose a list of particulars required for a quotation by the firm, in case it might be of value for R.E. officers abroad. The *D.F.W. Technical Instruction*, No. 64, of 31st December, 1924, refers to this firm.

Yours faithfully,

A. W. SPROULL, Captain R.E.

PROPOSED INSTALLATION OF "WALLACE-TIERNAN" CHLORINE GAS ADMINISTRATOR FOR WATER STERILISATION

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(2) Is the rate of flow constant throughout the 24 hours?

(3) If fluctuating, are fluctuations from moment to moment or only by wide amounts as between different times of the day? Are such fluctuations uncontrolled or controlled?

(4) Is it proposed to treat the water in the mains or in an open trench or reservoir?

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(9) Are filter beds or pressure filters employed?

(10) Have you at the proposed point of application a water pressure in the neighbourhood of 15-20 pounds to the square inch?

(11) If possible, kindly send us a rough diagram showing the general arrangement and route of the water from its source to the distributing system.

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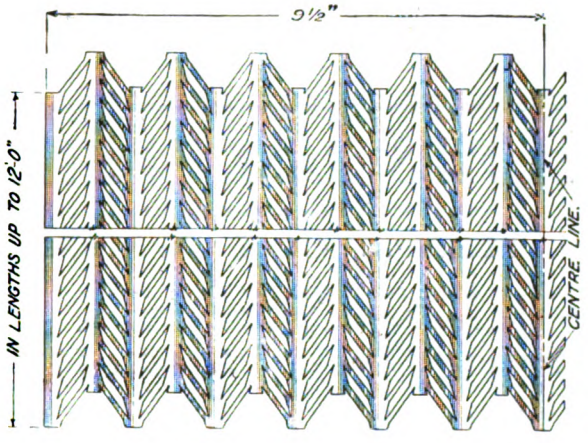

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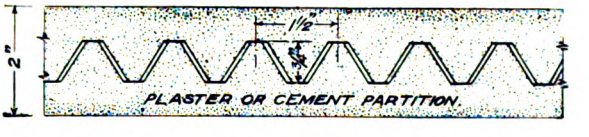

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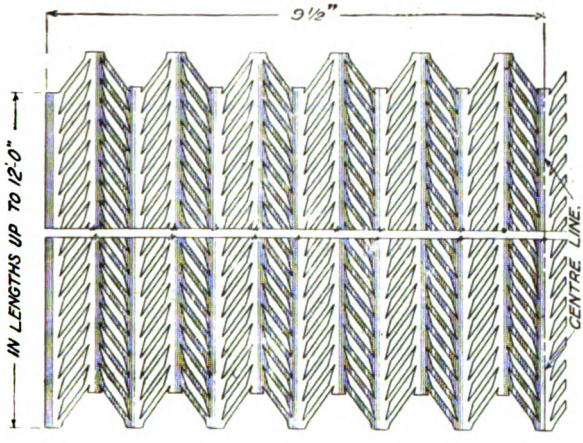

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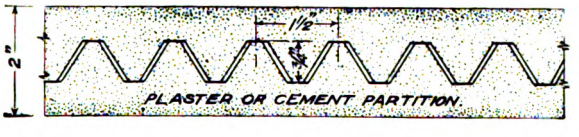

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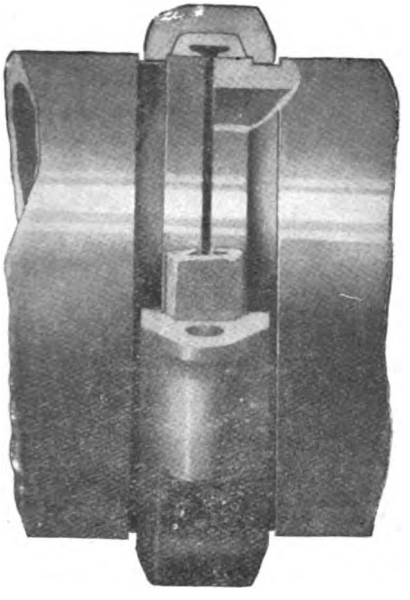

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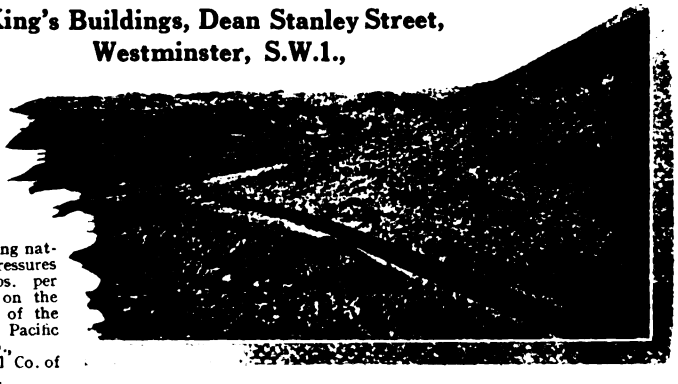

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THE second of the triennial prizes presented to the Corps by the Cooper's Hill Memorial Fund is for competition during the year 1926, and the Council of the Institution of Royal Engineers has chosen the following subject :—

"The effect of mechanicalization of the Army on the organization and employment of Divisional and Corps Engineers in the Field."

Essays must reach the office of the Secretary, Institution of Royal Engineers, not later than the forenoon of the 1st September, 1926. Essays must not be signed, but each must bear a pseudonym and the name of the writer enclosed in a sealed envelope must be attached.

The Cooper's Hill Memorial Prize is a bronze medal, a parchment certificate, and a sum of money, about £20.

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2. The Prize shall consist of (*a*) a book on Survey, Exploration, Travel, Geography, Topography, or Astronomy ; the book to be whole-bound in leather, and to have the Montgomerie book-plate with inscription inside ; (*b*) the remainder of the year's income of the Fund in cash.

3. The name of the recipient of the Prize shall be notified in the Corps publications ; and copies of the contribution for which the Prize was awarded shall be presented to the representatives of the donors.

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EARL KITCHENER AND HIS CRITICS.

"THE TRUTH ABOUT KITCHENER."

By V. W. GERMAINS ("A Rifleman.")

Published by John Lane, The Bodley Head, Limited.

This book is well worth reading and it may be described as being in the main a reasoned and effective reply to various criticisms of Lord Kitchener's action during the War which have appeared since his death, notably those contained in "1914," by Lord Ypres, "*The Tragedy of Lord Kitchener*," by Lord Esher, "*The World Crisis*," by Winston Churchill, "*The First World War*," by Col. Repington, and in certain writings and speeches by General Sir Ian Hamilton. The author has made a careful study of the facts and is in possession of a good deal of information from other than written sources. In the writer's judgment he has completely answered the criticisms with which he deals, and surely no one can peruse the book without feeling more than ever convinced of the magnitude of Lord Kitchener's services, of how he out-topped his contemporaries—a Triton among the minnows—and of how extraordinarily little substance or foundation there is to the criticisms levelled against him: further how small those criticisms would bulk, even if all of them were true, as compared to the services which he rendered.

It is regrettable, of course, that there has been all this criticism, but in the main it is due to the fact that the doctrines held and taught in pre-war days both by statesmen and responsible soldiers regarding the nature of the impending struggle were discarded directly war was declared and the opposing ones of Lord Kitchener adopted. In such circumstances it is natural that those whose forecasts were so mistaken should have felt mortified, nor can we wonder at some among them endeavouring to find flaws in the actions of him through whom their fallacies were exposed.

In a very interesting opening Chapter, Mr. Germains describes fully and accurately military doctrine in 1914, and shows how restricted was the vision of those who, at the War Office, did so much to prepare the Expeditionary and Territorial Forces. To the end of time, however, it will be a matter of wonder that, as Mr. Churchill writes, "Almost all professional opinion was agreed that the struggle would be short and that the first few weeks would be decisive."

Lord Kitchener, we know, took a precisely opposite view and with a sure instinct, realized that to force a great and proud military

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power like Germany on its knees must be the work of years. A further fact which the author brings out was that the satellites, military and civilian, who revolved round the War Secretaries and Sir John French from 1906 to 1914, considered Lord Kitchener ignorant of modern war conditions and incompetent to draw conclusions regarding them (Colonel Repington in one of his volumes writes of "Kitchener knowing nothing of modern military organization"); to this cause and possibly to the politicians' fear of a strong man, we owe it not only that Lord Kitchener was not brought to the War Office in 1911, but that his advice on matters of military policy was never even sought. Unaided then by the one man who could have helped them, the pundits framed their plans on the basis of a short war carried out so far as we were concerned on a "limited liability" principle, despite the terrible risk involved to the country. Not one single preparatory arrangement was made for the expansion which was ultimately seen to be inevitable directly we actually became involved in a world war.

Perhaps the shallowest and least convincing of the criticisms with which our author deals is that, when expansion was decided on Lord Kitchener was wrong in not taking the Territorial Force as the basis of expansion and Lord Esher is foolish enough to assert as a reason that Lord Kitchener knew nothing of the Territorial Force, of its organization or origin.

Let us recollect that the Territorial Force was formed and designed for *Home* Defence; its men were not liable for service overseas; its regulations were complicated, and would have required many and sweeping changes before the Force could be used as a framework for a General Expansion. New armies were wanted to fight *abroad* and for the war, and it was much simpler and more effective to raise them direct, apart from the Territorial Force, some of which at any rate would be always wanted for Home Defence. Further, as the writer knows from very direct personal experience, the Territorial Force Associations, as they were, had their work cut out and their time fully occupied in raising Second and Third Line Divisions, whilst the personnel of the Associations was not such as to make an appeal through them a very effective one. Lord Kitchener saw in a moment that what was needed was to get as many agencies to work as possible. The Regular Army recruiting agencies did much; the Territorial Associations captured Territorials, whilst Committees in the Great Towns in raising their own Kitchener battalions did invaluable work which could not have been effectively handled by the Territorial Associations.

Lord Kitchener did many wise things during the War but never a wiser one than when he decided not to carry out all the expansion through the medium of the Territorial Associations.

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Space does not permit of following the author through his replies to Lord Esher, Lord Ypres, Colonel Repington and others, but the writer knows sufficient of the subject to assure his readers that Mr. Germains is right in his facts and correct in his conclusions.

An interesting letter from General Ludendorff is included testifying to the magnitude of Lord Kitchener's achievement. We quote one sentence: "His great organizing powers alone would have sufficed to render Lord Kitchener one of the most remarkable and important personalities of the world war, perhaps the most distinguished England has ever had."

Despite the title of his book, the author, more especially in the chapters, " The Armies of the Somme," and " Lord Kitchener and his Successors," discusses a good many war questions unconnected with Lord Kitchener. He deals in some detail with the relations between Mr. Lloyd George and the soldiers, more especially in regard to the Roumanian Campaign. The question whether the Expeditionary Force should not in the first instance have been sent to Belgium instead of to France is also discussed. A few pages are devoted to Admiral Jellicoe and the Battle of Jutland, whilst the Staff arrangements in France are severely criticized. With these matters the writer has neither the space nor the special knowledge to deal, but it is obvious that the very extent of the field covered in a small compass of space gives to this portion of the book some appearance of discursiveness. The politicians come in for some hard knocks. The author speaks of these " earnest men " (Lord Esher's definition of the Cabinet) as resembling " a collection of maiden ladies meeting for tea and tittle-tattle, rather than a body of statesmen entrusted with the guidance of the country's fortunes at a supreme moment of destiny." This may sound severe, but if half the reports are true it is not overdrawn. The most regrettable thing in the book is an attack on a Corps Commander at Gallipoli whom the author saddles with a responsibility which was primarily that of the Commander-in-Chief. The writer hopes that this may be modified in subsequent editions as it is a blot on a stimulating and welcome publication.

H. M. LAWSON,
Lieut.-General.

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THE THOMASON COLLEGE, ROORKEE.

By Lieut.-Col. E. W. C. Sandes, d.s.o., m.c., R.E.

The Thomason Civil Engineering College at Roorkee in northern India has been intimately connected with the Corps of Royal Engineers since its foundation in the middle of the last century, and consequently its history, and a description of the methods now adopted there to train civil engineers for India, may be of interest to officers of the Corps. From the remarks of some visitors to the College I have gathered that they were surprised at the completeness of the courses of instruction and the outfit of instruments and apparatus used during those courses. It is to enlighten officers of the Corps on these matters that this article has been written, and though, as the subject is so large, the article has necessarily been prepared in a condensed form, I hope that it may be useful. Many good stories can be told of happenings at the College, but they must wait.

Like most institutions in a country in the process of rapid development the Thomason College grew from the smallest beginnings, step by step with the introduction of western methods of engineering into India. Its foundation may be traced chiefly to the necessity of training civil engineers in India itself for the construction of the great system of irrigation canals undertaken from 1817 onwards in the area around the upper waters of the Ganges river forming part of what was then known as the 'North-Western Provinces.' The construction of the Western Jumna canals began in 1817, and of the Eastern Jumna canal in 1822, and roads were made in many directions to open up the country, so that a demand for skilful engineers, conversant with the methods and needs of the country, grew very rapidly. When, however, the construction of the great Ganges Canal was started, Lord Hardinge, the Viceroy, realized in 1847 that an institution for training engineers must be opened at once to cope with the enormous demand for skilled supervisors and designers, and out of this emergency arose the Thomason College. Roorkee was selected as the site for a college as it is near the first 20 miles of the Ganges Canal in which are several engineering works of the greatest size, and also because it was already a centre of engineering from the presence of many officers of the Bengal Sappers and Miners.

Lieutenant R. Maclagan, R.E., the father of Sir Edward Maclagan, late Governor of the Punjab, was appointed Principal of the College at Roorkee in the 19th October, 1847, assisted by a Headmaster, a

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Drawing master, and two Indian teachers. The classes were three in number, one for training candidates for appointment as Sub-Assistant Civil Engineers, another for training European N.C.O.'s and soldiers as Overseers, and a third to train Indians as Surveyors. The College, however, did not become known as the Thomason College till 1854, after the second Punjab War, when it was reorganized and named after Mr. Thomason, the Lieutenant Governor of the North-Western Provinces, the new scheme including the admission of officers of the Royal and East India Company's armies for training as engineers, and a great enlargement of the College buildings. Many young officers of the Royal Artillery and Royal Engineers joined the institution as students, and it began rapidly to rise towards its present position and reputation.

From the foundation of the College in 1847 to the year 1891, all the Principals were Royal Engineers. Lieut. (afterwards Colonel) R. Maclagan (1847-1860) was succeeded by Capt. E. C. S. Williams, (afterwards General Sir E. C. Sparshott Williams, K.C.I.E. Colonel Commandant R.E. (1860-1862),and then by Major (afterwards Colonel) J. G. Medley (1863-1871), Major (afterwards Colonel) A. M. Lang (1871-1877), and Major (afterwards Colonel) A. M. Brandreth (1877-1891). A departure from precedent then occurred in the appointment of Colonel F. D. M. Brown, V.C. (1891-1892), and later Major (afterwards Lt.-Colonel) J. Clibborn, C.I.E. (1892-1902), both of the Indian Staff Corps, as the corps of officers of the Indian Army was then called. However, a Royal Engineer was again appointed in 1902 in the person of Capt. (later Lieut.-Colonel) E. H. de V. Atkinson (now Major-General Sir E. H. de V. Atkinson, K.B.E., C.B., C.M.G., C.I.E.) who held the post of Principal from 1902 till 1915, almost equalling the record tenure of Colonel Brandreth. After an officiating period of one year by Mr. E. F. Tipple, Professor of Mathematics, the next Principal was Mr. W. G. Wood, C.S.I. (1916-1921), a retired Chief Engineer of the Public Works Department, and finally, after four years' experience as a Professor before the war, the writer was appointed Principal in 1921. Many R.E. officers have officiated as Principal, or have been Military Assistant Principals or Professors, among them being Major Oldfield (1852-1856), Major A. Cunningham (1876), Lieut. (afterwards Lieut.-Colonel) J. H. C. Harrison (1881-1882), Capt. E. D. Bullen (1894 and 1897-1898), Lieut. (afterwards Lieut.-Colonel) H B. D. Campbell (1898 and 1905-1910), Major W. A. Gale (1898), Capt. (now Bt. Lieut.-Colonel) D. K. Edgar, and Lieut. T. H. L. Spaight. It will be seen from these records that, during the 78 years of the existence of the Thomason College, 8 of the 11 Principals have been R.E. officers, and that at least 16 R.E. officers have served on the staff, so that the College has had a very close connection with the Corps. At one period in its history

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there were as many as 3 Military Assistant Principals (all R.E. officers), but normally there was only one, and in 1910 the post was abolished as there was then a large staff of civilian Professors. Since that date no officer of the Corps has joined the staff, which is now recruited by advertising any vacant post and assembling a Selection Committee in India to recommend a candidate for it.

After the Indian mutiny a new Thomason College was built on the present site, and additions and extensions were made in later years till the building reached its present dimensions, complete with 6 lecture theatres, 2 large engineering model rooms, class rooms, offices, a library, a gymnasium and Convocation hall, scientific laboratories, a large printing press and photo-mechanical department and with mechanical and electrical workshops in a separate block. The classes under instruction have been altered from time to time in accordance with requirements. I will deal briefly only with the existing classes and courses as these are designed for the most modern needs in northern India.

The Thomason College now admits students to the following classes :—

(*a*) Civil Engineer Class (*b*) Overseer Class (*c*) Draftsman Class and of these by far the most important is the Civil Engineer Class. Students who qualify in this class can rise to great heights in Government service in India, several having already reached the rank of Chief Engineer of a Province. The most notable example of success from this class is that of Sir William Wilcocks, the famous engineer of Egypt and Mesopotamia. Admission is gained through a competitive examination held yearly under the auspices of the College at various centres in northern India, including Roorkee itself, and, to be eligible to compete, candidates must at least have matriculated at a University (with certain special subjects such as Drawing), or have gained a corresponding qualification at a European school, must be between 17 and 21 years of age, must be domiciled in the United Provinces, Central India, Bihar, Orissa, the Punjab, or certain other northern territories, and must have the necessary certificates of physical fitness and moral character. Candidates are not taken from the provinces of Bengal, Bombay, or Madras, as these territories have their own engineering colleges at Sibpur, Poona and Madras respectively, nor are any taken from Great Britain or other countries outside India and Burma. Europeans and Indians compete for admission at Roorkee under identical conditions. Only 30 vacancies are offered yearly in the Civil Engineer Class, and the popularity of the College may be gauged by the fact that 274 candidates sat for these 30 vacancies in June, 1925.

The Civil Engineer Class course is one of 3 years' duration. It approximates to the degree standard in engineering at British universities. The first year is devoted mainly to pure mathematics

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and science, the second year chiefly to more advanced pure and applied mathematics, science, surveying, and some civil, mechanical and electrical engineering, and the third year almost entirely to civil engineering (including designs), with the addition of more mechanical and electrical engineering and surveying (including astronomy). A most important test of a student's practical ability takes place in the 3rd year, in which, after some preliminary projects which are corrected and criticized, a large 6 weeks' engineering project is set by an outside examiner in Irrigation or Railway design. The 3rd year students go into camp for the first 3 weeks of this project period, and each one works alone across country with his own instruments and gang of men, returning to Roorkee to complete his reports, designs, calculations, estimates and survey plates when he has finished his out-door work. This test, which carries a large number of marks, effectually eliminates the pure theorist from the top half of the class, and brings to the fore the man of common sense, ability, and character. Before the end of each session, in June, there is a final examination, in which every student must qualify in the various groups of subjects studied during the session, if he is to remain in the College. Mid-sessional examinations also are held in February. The College session starts on the 16th October and ends on the 15th July, being followed by a vacation of 3 months during the unhealthy monsoon period, and at Christmas there is 10 days leave. The final examinations in the heat of June are rather a trial, but fever is so rampant at Roorkee in the rains that it would probably be difficult to hold the examinations in July, August or September.

When the Civil Engineer Class student (then, say, 23 years old) qualifies at the end of his course, he is given a certificate which is either 'Higher' or 'Ordinary' according to his total of marks,* and he then as a rule goes as an apprentice (or student) to the Public Works Department for one year to learn practical methods of work and the control of labour. At the end of this year, if his reports are good, he is posted to the Department as an Assistant Executive Engineer (or an Assistant Engineer) on probation for another year, and thus he starts his career in Government service as an officer. There is an all-India engineering service, known as the 'Indian Service of Engineers,' which is recruited both in India and from among qualified engineers in Great Britain. Appointment to this service is what every student desires, for in it he can rise to the highest rank and he starts on good pay. Roorkee has hitherto been allotted 9 or 10 vacancies in the I.S.E. (the Indian Service of Engineers) each year, which is greatly in excess of the number given to any other engineering college in India, and thus the top nine or

*The College cannot give a degree, as it does not belong to any University, and has no Faculty of Engineering.

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ten qualified students pass into this all-India service and may be employed anywhere in India though they are usually kept in their own provinces. The remaining students of a batch are usually offered appointments (after apprenticeship) in the Provincial Engineering Service of their province on a lower scale of pay, but some of these men may hope to be admitted to the I.S.E. later by selection, if specially brilliant. A few passed students enter the service of Indian States, having as a rule been admitted to the College as 'State students' who have qualified but not gained places in the competitive examination, and whose cost of training at Roorkee is paid by their States in return for a claim on their services when they leave college.

On confirmation as Assistant Executive Engineer in the Indian Service of Engineers a young Indian or a European domiciled in India, starts on a salary of Rs. 375 a month (say £335 a year). After ten years he may be getting Rs. 875 a month and will probably then be an Executive Engineer, in which grade his maximum will be Rs. 1,375 a month at 24 years' service or over. At about 20 years' service, however, and sometimes earlier, a good man should certainly have been selected for the Superintending Engineer grade where his pay rises from Rs. 1,750 to Rs. 2,150 a month, and later he may have a chance of selection to Chief Engineer on the handsome salary of Rs. 2,750 rising to Rs. 3,000 a month, or say £2,700 a year. It is not surprising, therefore, that competition is very keen for entry to the I.S.E. Those who fail to enter this service, but gain appointment in their provincial service as Assistant Engineers, start on a salary of Rs. 250 a month, rising to Rs. 750 a month, but they are not debarred from selection later to the higher service. Pensions are given on a fairly liberal scale, but candidates recruited in India for the I.S.E. are not eligible for the additional 'Overseas Pay' and passage concessions given to men from Great Britain as a set off against the expenses of leave out of India and the education of children in England.

The former Upper and Lower Subordinate classes of the Thomason College were abolished a few years ago, and the Overseer Class was substituted, with a scope and standard of instruction between those of the abolished classes. The Overseer Class offers a good course to men wishing to qualify as subordinates. Many of the more successful students in this class are taken into the Subordinate Engineering Service of the Provincial Government after a suitable apprenticeship. In this service the scale of pay rises from Rs. 80 to Rs. 227 a month, but men are eligible for selection to the Provincial Engineering Service if particularly brilliant. Overseer Class students who fail to get permanent Government appointments often get temporary ones, or service with Indian States or private firms. As in the Civil Engineer Class, certain educational and other

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The Thomason College.

COLONEL MACLAGAN, R.E.
(The First Principal, 1847-60).

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The Quadrangle.

The Main Corridor.

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qualifications are required before a man can appear for the entrance examination for the Overseer Class at Roorkee. Forty vacancies are offered each year, and 250 candidates sat for them in June, 1925. The course is of only 2 years' duration, and much lower in scope and standard than the Civil Engineer Class course, the training being of a less theoretical nature.

The Draftsman Class is of a lower standard again and entirely specialized. A certain number of men are admitted to it annually (about half a dozen) after an elementary examination. There is no limit to the time they spend at the College learning draftsmanship, and they are given certificates when passed as proficient. They work under a special Indian instructor, and pay no fees. Usually the whole Draftsman Class does not exceed about 20 men.

There is no all-India Engineering College to take the place of Cooper's Hill, which was closed many years ago in England. The Thomason College is a provincial institution under the control of, and belonging to, the Government of the United Provinces, but it takes students from certain other parts of India, particularly the Punjab, on special terms, and trains them mainly for Government service, which offers the best prospects at present for the ambitious young engineer. The sons of residents of the United Provinces are given certain concessions at Roorkee, such as scholarships and training at Government expense (except for a small monthly College fee) which other students do not get. Many Punjabi students gain entrance to the Civil Engineer Class, and the Punjab Government pays the cost of training of the first ten Punjabis on the list (about Rs. 10,000 per student for the complete course), but other students domiciled outside the United Provinces have usually to meet this expense themselves. The United Provinces' students of this Class pay an educational College fee of only Rs. 24 per mensem during each session, and Rs. 40 for their final examination, so that the training is far cheaper in their case than that of any University in England. There are, of course, other expenses such as recreation and club subscriptions, and messing for European students, but the United Provinces' Government is liberal in scholarships to its own students and the Punjab Government gives some scholarships to Punjabi students. In addition, all the Civil Engineer Class students are eligible to compete for certain valuable prizes, the top man receiving a prize of Rs. 1,000 on passing out.

Most of the Civil Engineer Class students at the Thomason College are Indians. Nowadays, out of the 90 students of that class, about 70 are Hindus and 10 are Mohammedans, while the remaining 10 may be Europeans. The Indians come almost entirely from the Indian universities such as Allahabad, Lucknow, Aligarh, or the Punjab University at Lahore, and many have already got degrees in Arts or Science before entry at Roorkee. They are thus, as a

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rule, two or three years older than the European students, who come direct from the few European schools in the hills at Naini Tal, Mussoorie and Simla. The Europeans have not generally the same mathematical and scientific knowledge before entry which the Indians possess, and this accounts partly for the small number now gaining entry to the college in open competition.

The engineering training given at Roorkee is more theoretical than it was a few years ago, and follows more closely the systems adopted in the engineering colleges of British universities, but it still remains, especially in Surveying, rather more practical in nature than the British training, except perhaps in Mechanical and Electrical Engineering. The immediate needs of a country must necessarily dictate to some extent the nature of the training to be given to engineers intended for that country. Machinery, in Great Britain, takes the place of the cheap manual labour of India, hence special training in Mechanical Engineering is more important in these days to the civil engineer in England than to one who will probably remain in India. Mechanical and Electrical Engineering, however, are by no means neglected in the Roorkee course, but form an important part of it. They are likely to take a more prominent place in future years, as machinery gradually replaces manual labour. On the other hand, practical Surveying is more important to the civil engineer in India than in England where trained Surveyors are always procurable. Hence the extra time and attention devoted at Roorkee to Surveying, which find their counterpart in the more advanced instruction in Mechanical and Electrical work in Great Britain. The student from Roorkee has a splendid reputation in Surveying, founded on the fact that he is a trained *practical* surveyor before he leaves the College, where he has been accustomed to use the very latest patterns of tacheometric levels and theodolites, not working in a squad as in England but alone in the field or with only one companion. For the use of the 3rd Year students the Thomason College has now 33 of the latest pattern of Cooke's levels, each instrument being identical and thus allowing of competitive work on equal terms. The Professor of Surveying and Drawing is an ex-officer of the Survey of India Department, and an expert in the design of instruments, with 17 years' experience at the College.

The senior staff of the Thomason College, as authorised at present, consists of a Principal, 7 Professors, and 2 Assistant Professors. Three Professors are authorised for the Civil Engineering Department, one for surveying and drawing, one for pure and applied mathematics, one for electrical engineering and physics, and one for chemistry, geology and mineralogy. The Assistant Professorships are in mechanical engineering, and surveying and drawing. Some of these posts are vacant at the moment. The senior staff includes both Europeans and Indians, as also does the Lecturer staff. Some

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changes in the number and allotment of Professorships and Assistant Professorships are under consideration. Each Professor is in sole charge of his Department, or sub-Department, but the College Board of Studies offers opportunities for the meeting of the whole senior staff to discuss any educational matters. There are now 10 Lecturers, Indian and European, working under the orders of the various Professors in the instruction of the Civil Engineer Class, and, for the Overseer Class, a staff of 6 Indian Instructors. In addition there is the staff of the College Press and Photo-Mechanical Department (a Government concern, run on a commercial basis and employing trained and paid workmen), a staff of foremen and mechanics for the College workshops and electrical installation, a clerical establishment for the College office, a Librarian for the library of 29,000 volumes, and a Personal Assistant in charge of the buildings, grounds, and servants.

The College has its own dairy, mineral water factory, stores, and hospital, and an electrical supply system giving current for various motors and for electric lights and fans in the main building and the Principal's bungalow. The drinking water comes from enclosed wells whence it is pumped direct by electrical power into overhead reservoirs, while water for other purposes is obtained from the Ganges canal through a separate pipe system. All the students live in hostels grouped in rear of the College, and each student of the Civil Engineer Class has a room to himself, supplied with Government furniture. Most of the staff have detached bungalows with large gardens. In fact the institution is absolutely self-contained, as is required by its situation 500 miles from Allahabad whence it is controlled. It is entirely under the civil administration, and the Principal corresponds only with the Director of Public Instruction and the Educational Secretary, who in turn work under the Minister of Education and Industries of the United Provinces. Till 1924 there was a class of British N.C.O's. under training to become Subordinates in the Military Works Services, but that class no longer exists, and the College now caters almost entirely for the Public Works Department (Irrigation or Buildings and Roads branches) and for the Indian Railways and some Indian States, though the training is designed for utility in any engineering appointment.

The students are encouraged to take part in all recreations, games, and sports. For social purposes there is an Indian Engineer Class Club where all the Indian students of that class can meet to enjoy a game of billiards or read the papers, while the European students have a mess run on lines identical with those of a military officers' mess. The Indian students make their own arrangements for messing according to their castes or religions. Athletic Sports are held annually in December, and a Regatta on the Ganges Canal in June. The College has now four 4-oared outrigged sliding-seated boats

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of clinker build, and a number of double-sculling, pair-oared, and single-sculling boats, all from Salter's at Oxford. Tennis is extremely popular, and also racquets and squash racquets. There are ten concrete tennis courts, and an excellent cricket field where matches are played in the cold weather. Hockey and football are played also, but the latter is not very popular. All the European students, and most of the Indians, are now enrolled as soldiers, either in the Indian Auxiliary Force (Europeans) or the Allahabad University Training Corps (Indians), and form creditable, if small, units. In January each year the College takes on the K.G.O. Bengal Sappers and Miners in an 'Olympic Contest' for a challenge cup, the events being cricket, football, hockey, tennis, racquets, squash racquets, rifle shooting, golf, billiards and chess, and a very keen competition generally results, the College having the greater number of wins up to date. Every endeavour is made by these means to keep the students well occupied physically throughout their time at Roorkee, both for their health and pleasure and to train them for the arduous life of a civil engineer.

The general trend of modern policy is to make India self-supporting and self-contained. The Thomason College tries to further this policy by supplying northern India with engineers born, educated, and trained in India. Whatever may be the advantages of travel and engineering education in Great Britain, the parents of students in India have to consider the enormous expense of sending their sons to be trained in Great Britain (probably at least £1,500 for a degree in engineering); and the training in civil engineering available at Roorkee, which opens prospects in India equal in all respects to those of men trained abroad, is becoming year by year more popular as shown by the rapidly increasing competition. There should be no reason why this training, given by experts with long experience of India, should not be made more valuable for a student destined probably to make his career in India than that available in Great Britain, and this is the ambition of the staff of the Thomason College.

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THE EARLY YEARS OF THE ORDNANCE SURVEY.

(*Continued.*)

VIII. The Survey of Ireland.

The Seventeenth Century Surveys of Ireland.—The modern Ordnance Survey of Ireland was begun in 1825, but this was by no means the first official survey of the country, even if we restrict the meaning of the word to the measurement of the land and its boundaries and the making of maps from such measurements. Of course, in a certain broad sense, even such an examination into the condition of a country as resulted in the Doomsday Book is a survey, and is so quoted by the Select Committee of 1824. But in the seventeenth century the obvious convenience of making maps to illustrate such an investigation was fully realised, and we find that Strafford, who was Lord Deputy of Ireland from 1633 to 1639, caused maps to be attached to his surveys of Tipperary and other countries. In a report on the Strafford survey of Tipperary made to the Comissioners of the Commonwealth, it is stated :—

"We have perused certain small books bound up in parchment . . . on the outside of which books are set down . . . the names of the parishes respectively belonging to that baroney. In the inside of the books, before every parish, are set down the names of the jurors, being generally six in number, and underneath the said names, this memorandum within, that they being all duly sworn upon the holy Evangelists, have set forth the bounds and meares, names and by-names, of all the quarters, plow-lands, and other denominations of lands lying in the parish, together with all the owners and proprietors of the said lands. . . In the next place is sett downe the names of the surveyors who admeasured the said parish . . . the method and proceeding in the description of every parish is as followeth :—

1st The number of surrounds made by the instruments, in each parish respectively. . .

2nd A description of each surround, more particular, according to the name of the land so surrounded ; the quality of the said land. . .

3rd At the end of each surround is an observation made of what castles, houses, mills or other edifices, as also what offices or other emoluments were found upon it.

"We further humbly certifie that, besides the sayd bookes, wee find a very fair county map, containing the several barronyes . . as also smaller maps of particular barronyes, and of particular parishes, most of which, soe far as we can discover, are very entire and perfect. The said plotts or maps expressing also the quality of the said land, whether arable, pasture or meadow, etc."*

* Quoted in Portlock's *Memoir of General Colby.*

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Seventeenth century mapping work was fairly accurate when the area mapped was not very large. A seventeenth century parish survey would not differ much from a modern exact survey. The surveyors of that age were well accustomed to the accurate use of the chain in measurement; they were also acquainted with the uses of plane-table, compass, and circumferentor. The latter instrument had, however, no telescope, and was only provided with "sights"; and, of course, the arcs were not very finely graduated. Given the instruments available, they made as good traverses as we, perhaps, should. But, with such instruments, considerable errors accumulated in the traverses of large areas. There exist many admirable property plans dating from this period; the "platts" or "plotts" of parishes, or small properties, stand comparison with modern plans fairly well. Our ancestors of eight or nine generations ago were by no means as unintelligent as we are sometimes inclined to suppose.

The best known of all the early surveys of Ireland, and the first comprehensive large scale official mapping ever undertaken in the British Isles is the Down Survey.

The Down Survey.—This celebrated survey was undertaken to enable a systematic "plantation," or settlement, of English soldiers and adventurers, to be carried out in Ireland. Such a plantation, detestable as it is from a modern point of view, is a proceeding which history often has to record. In the case of Ireland it was Queen Mary who carried out the first systematic plantation, namely, that of Leix and Offaty; and from this example it is clear that religious differences were not necessarily a primary cause of such a policy. The settlement which necessitated the Down Survey did not take place for about a hundred years after Mary's plantation, and was a sequel to the "Rebellion" of 1641, which largely did take the form of a war of religion. For eight years after this date, Anglicans, Presbyterians and Roman Catholics, adherents of King, or Covenant, or Commonwealth, butchered each other with a ferocity inspired by racial and religious hatred. Then, in 1649, Cromwell came over with his disciplined army, and the rebellion was shortly at an end.

In the year 1653 an Act was passed, under the Commonwealth, for the *Satisfaction of the Adventurers for Lands in Ireland, and of the Arrears due to the Soldiery there, and of other publique Debts.* In the preamble it is stated that:—

"Whereas many well-affected persons, bodies politique and corporate, did subscribe and pay in, upon several Acts and Ordinances of the late Parliament, divers considerable sums of money by way of adventure towards the suppression of the late horrid rebellion in Ireland, which said sums of money were, by the said Acts and Ordinances, appointed to be satisfied by several proportions of the lands of the rebels there,

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as soon as the said rebellion should be appeased; and whereas also several other great sums of money are grown due, and in arrear unto the officers and soldiers who have been employed in reducing the said rebels, and to sundry other persons either for arrears yet unsatisfied, moneys lent, or provisions or other supplies furnished for the publique service; and whereas by the blessing of God upon the forces of this Commonwealth, the said rebels are subdued, and the said rebellion is appeased and ended, and it is hereby declared to be appeased and ended."

The Act appointed a Committee in London for "the drawing of lots for ascertaining to the said adventurers where their dividends of lands shall be," and a Commission in Ireland to arrange for the distribution of the lands. In the Instructions to the Commissioners full power and authority was given to them to put in execution all the necessary steps for the "exact and perfect survey and admeasurement of all and every the honors, baronies, castles, manors, lands, tenements, and hereditaments forfeited," as also those belonging to the Crown of England or the Church; and a surveyor-general and assistants were to be appointed.

An order was then issued, putting Mr. Worsley, surveyor-general, and Doctor William Petty, jointly in charge of the work: "It hath also been ordered that Benjamin Worsley, Surveyor-General, and Doctor William Petty, should be joyntly authorized and impowered to carry on the said work, and to imploy such fitt and able artists in it as they should think fitt." They were to survey the lands belonging to the rebels,

"in the County of Lowth and the County of Leitrim, and also all the lands, tenements and hereditaments of, or lately belonging to all and every the rebels in any of the baronies within the County of Cork, Kilkenny, Longford, Lowth, Cavan, Monaghan, Ffermanagh, Sligo, and Mayo. . . You are to survey, or cause to be surveyed and admeasured with the instrument, all the lands mentioned . . . You are carefully to survey and admeasure with the instrument the out-meares and bounds of all and every the baronies within the counties mentioned. . . You are to give into the office of the Surveyor-General fair plotts and bookes of survey . . . together with bookes of references answering to the said plotts, in which you are at large to describe the boundes and metes of all the said forfeited townes and lands . . . and to set down what you find observable in them." . .

Doctor William Petty was born in 1623, and was the son of a clothier at Romsey, in Hampshire. In 1652 he was appointed physician to the Army in Ireland, and thus came into touch with the question of the survey of the forfeited lands. Before his arrival in Ireland, and before the appointment of the Commission mentioned above, it would appear that Worsley, the Surveyor-General, had been carrying out some surveys for the purpose. Dr. Petty had a poor opinion of Worsley's methods, and proposed a system of his own, which was accepted. He was given the contract for

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the operation, and made a fine fortune out of it. The work was, considering the methods and instruments available, admirably carried out, and in a short space of time. The difference between Worsley's scheme and that of Dr. Petty was, briefly, that Worsley worked on the unsound principle of surveying small "surrounds" and fitting them together without adequate checks; whereas Dr. Petty realised the importance of working, as far as possible, downwards, from the whole to the part, and of establishing checks at every stage of the survey. He does not appear to have made use of triangulation, although the method was known at the time, having first been employed by Willebrord Snell, in Holland, in 1617.

Sir Thomas Larcom, in his history of *The Down Survey*, says that:

"Worsley was carrying on the survey for grants and forfeitures . . . but it remained for Dr. Petty to originate the idea of connecting the separate operations into a general survey of the three provinces which were not comprised in the Strafford Survey. His great step was making territorial and natural boundaries the main objects, instead of estate boundaries alone."

Dr. Petty introduced a system of checks into the method of carrying out the surrounds or traverses. He instructed the surveyors,

"by intersections, to determine the true place of all townes, churches, castles, known houses, mills, raths, etc., within each respective surround . . . for the better examining and correcting your works." He also laid down the rule that "the common lines of each barony are to be run together by two distinct measurers at once, their respective servants keeping double reckoning of the chains alsoe." Again, "as often as conveniently you can, you shall protract your large surrounds before you doe the inworke of the same."

Most of the barony maps are on the scale of 160 Irish perches to one inch, or 1.6 inches to one mile. But about a quarter are on the scale of 0.8 inch to one mile, and a few on the 3.2 inch scale. The parish maps, from which the barony maps were reduced, were on the scale of 3.2 inches, or 6.4 inches, to the mile.

With regard to the name *Down Survey*, the work was apparently so called because it was set "down" on paper. The expression is used in both the reports of the Committee on Dr. Petty's proposal issued in 1654. Dr. Petty's surveys were carried out in two parts. The first for the settlement of the Cromwellian soldiery, under an agreement between Worsley and Petty, dated December 11th, 1654, and the second for the settlement of the "adventurers," under an Order in Council of September 3rd, 1656.

Until a few years ago it had been supposed that the most authoritative copies of the original barony maps were preserved in the *Bibliothèque Nationale* at Paris, but the Earl of Kerry

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has shown that most of the originals exist and that the bulk of them are amongst the papers of the Marquises of Lansdowne.

"The maps were at Lansdowne House in an old chest, where, to all appearances, they had long rested. With them were also found some letters and memoranda which show that they had been in Dublin, in the hands of the first Lord Lansdowne's agent, at the end of the eighteenth century. It seems probable that they were sent over to London after his death, and that they have remained there ever since. There can be little doubt that they form a portion of the original survey maps bequeathed in his will by Sir William Petty, of whom Lord Lansdowne is a lineal descendant."*

More than half of the original Down Survey baronial maps are in the Lansdowne collection; almost all the remainder are in the Public Record and Quit Rent Offices in Dublin. The barony maps were never engraved, but were used in the preparation of county and provincial maps. With regard to the French copies, Lord Kerry writes:—

"As is generally known, there are in the *Bibliothèque Nationale* at Paris two large volumes of these barony maps, which, though long recognised as copies, are important as constituting the only complete set in existence. They comprise all the baronies of Ireland (215), except those of Roscommon, Galway, and parts of Clare and Mayo, which counties having been surveyed under Strafford's administration, and afterwards reserved for the transplanted Irish, were not dealt with in the Down Survey."*

The two volumes of the Down barony maps in the *Bibliothèque Nationale* in Paris have a curious history. They were copies of the original maps, and were, apparently, being sent from Ireland to London to be engraved, when they were captured by the French at sea in 1707 and found their way to the *Bibliothèque Royale*. In 1786 King George III. asked that they might be restored to Ireland, but the French Government refused. They were, however, copied by hand and the copies are now in the Public Record Office. Photozincographic reproductions of these copies were made, in later years, at the Ordnance Survey Office, Southampton, where these reproductions can be purchased.

The Select Committee on the Survey and Valuation of Ireland.—This Committee, which reported on the 21st June, 1824, had specially in view the more equal apportionment of the local burthens collected in Ireland. The Committee reported that there were great variations in the methods of assessing the local taxation, and that the assessment was inequitable because areas and values were inaccurately reckoned. Townlands, ploughlands, gneeves, cartrons, tates, and other denominations of land are

* Proceedings of the Royal Irish Academy. Vol. XXXV., Section C, No. 12, 1920. The Lansdowne Maps of the Down Survey, by the Earl of Kerry.

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mentioned; and it is stated that however the names might vary, the evil seemed universally the same, and that the inequalities had continued for a very long period to the year of the report. It was stated, also, that a Select Committee of 1815 had reported in favour of rendering the assessments more equal, by correcting the defects arising from the fixing of the county rate according to the old surveys, calculated on land values altogether out of date.

The report mentions the Down Survey in these terms:—

"The most extensive and valuable survey of Ireland was undertaken by Sir William Petty, under a commission dated December 11th, 1654; it was executed in consideration of a payment of 20s. by the day, and of 1d. an acre for the grantees obtaining possession of the lands. This survey was laid down with the chain, and with wonderful accuracy, considering the period at which it was executed."

It is added that the last official survey (up to 1824), of an extensive nature, made in Ireland, was that of the Forfeited Lands, in the reign of William III; it comprised about two million acres.

The area of Ireland was stated to be about 12 million Irish, or about 20 million English, acres, divided into four provinces, 32 counties, 252 baronies, and 2,400 parishes, with further civil sub-divisions, generally known as townlands. These latter "are the ancient and recognised divisions of the country; they form the basis of the Down Survey; they have long been used" for the assessment of local rates. The Committee, therefore, reported that any new Survey must give the boundaries of the townlands. Major Colby gave evidence that the additional time required to plot the townland boundaries on the map would not be very considerable, provided that the boundaries were previously set out on the ground; and Mr. R. Griffith stated that there would not be any great difficulty in ascertaining the boundaries in question. It may be noted that townlands were of very varied sizes, but were most frequently in the neighbourhood of two or three hundred acres.

At this date, 1824, the materials available for assessment were: The Down Survey and the Strafford Survey of the seventeenth century, with some modern surveys in a few cases. No doubt the modern survey of Roscommon, executed by Mr. W. Edgeworth and Mr. R. Griffith was a good one of its kind, but such surveys were few and far between. As to the seventeenth century surveys, not only did they lack the precision to be expected from modern work, but the assessments based upon the ancient values of the land were often very inequitable. The Chairman of the Committee, Mr. Spring Rice, said that, as regards the County of Limerick, where he resided, the contents of the rating book were based upon ancient estimates, which did not agree entirely either with the Down Survey or with any other authority which he knew to be in existence. He also said that there was a general feeling in favour of the old

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established boundaries, namely, those of baronies, parishes and townlands; they had been, in many cases, ascertained by judgments in courts of law, "and they form the foundation of the Down Survey now in existence, and the best document of the kind which can now be referred to in Ireland." He expressed the opinion that there was no remedy for the evils complained of, "except through the means of a new survey and valuation."

Colby's evidence before the Select Committee is valuable, because it shows the general ideas which he had upon the subject of a large scale survey, before he was actually required to organise such an undertaking. He said that he thought they could complete 2,000 square-miles of survey during the first year and an increasing area in subsequent years. In his opinion a scale of six inches to the mile was large enough to show those divisions of land, called townlands, which varied from 50 to 400 acres. It is interesting to note that he had then no knowledge of the Down Survey. He was opposed to officers of Engineers taking any part in the valuation of the land surveyed. He gave evidence that the work would take at least seven years and would require 25 to 30 officers, with five or six surveyors to each officer. We may say, in fact, that, making allowance for labourers and office staff, he seems to have contemplated an establishment of about 400 officers and men. As a fact, he under-estimated both the time and the establishment necessary.

He was not favourable to the idea of employing surveyors temporarily, and he insisted on the whole staff being under efficient control. He would not accept the idea of allowing the boundaries of the townlands to be surveyed by local surveyors and then fitted on to a scientific framework; he stated that he could not construct a map by fitting townland surveys together and he gave evidence that the cheapest, most rapid and most accurate method of making a large-scale map of Ireland would be to create an organisation for the express purpose and to give up any idea of adapting local surveys.

In all these general considerations his advice was undeniably sound, and it was almost immediately acted upon.

A surveyor called Hyett gave some curious evidence. He had been employed under Mudge some years before, on the survey of the detail for the one-inch map of England; and he says that, "the corps of surveyors, of which I was a member, being disbanded, I was appointed professor of military drawing to the Royal Military College, and one of my duties was to instruct the cadets in surveying and sketching." The corps of surveyors and draughtsmen had, thus, ceased to exist before 1824. Hyett gave the remarkable advice that the survey of the detail should precede the triangulation! Fortunately, no one else was of that opinion.

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Mr. W. Edgeworth, the celebrated engineer, gave an interesting account of his surveys of the counties of Longford and Roscommon, and also produced specimens of the large-scale maps of Bavaria. These were on the scale of 1 : 5,000, or about 12 inches to the mile, and were based upon primary and secondary triangulations, the filling up of the interior being "completed by a peculiar species of plane-table and in order to do away with the inaccuracies of the common chain, the triangulation is carried down on paper to the most minute corners of fields." The Committee also mentioned the French 1 : 2,500 *cadastre*, which may be said to have commenced in 1803 and was costing about £120,000 a year. This sum frightened the Committee, which stated that "the delay of the work as well as the increase of expense, seem to have been the result of the minuteness of the survey, which extends to every distinct field; a minuteness which, for many reasons, your Committee consider to be unnecessary and inexpedient to be sought for in the proposed Survey of Ireland."

Before the appointment of this Committee, the House of Commons had, in the same year, 1824, voted £5,000 towards the execution of a Trigonometrical Survey of Ireland, and had resolved, "that it is expedient, for the purpose of apportioning more equally the local burthens of Ireland, to provide for a general Survey and Valuation of that part of the United Kingdom." The Committee had now to make definite recommendations.

Recommendations of the Select Committee of 1824.—"Whilst your Committee express their belief that the execution of the survey cannot be placed in better hands than in those of the Ordnance Officers, they cannot but add, that it is expedient to give much greater dispatch to this work than what has occurred in the Trigonometrical Survey of England. That great work, highly creditable as it is to the individuals by whom it is conducted, has already been 33 years in progress, and yet it still wants one-third part of its completion. It ought to be added, however, that the operations of the Ordnance suffered interruption during the war." . . .

"Your Committee perfectly agree with Major Colby that a central and effectual control is indispensable." . . .

"The best scale for effecting the intended Survey appears to your Committee that of six inches to the English mile." . . .

"The new Survey should supersede all local topographical proceedings, whether under the authority of Grand Juries or otherwise."

The Committee also reported that they had considered what should be shown on the maps, and they stated that a survey showing the boundaries of baronies or parishes would not be detailed enough, whereas a "Survey by Fields" would be too expensive and slow. They, therefore, advised the survey of townland boundaries, but not a field to field survey. This restriction was subsequently removed.

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After again pointing out the necessity for proceeding as rapidly with the work as would be consistent with accuracy of execution, the Committee concluded :—

" It is not unworthy of remark that all former Surveys of Ireland originated in forfeitures and violent transfers of property ; the present has for its object the relief which can be afforded to proprietors and occupiers of land from unequal taxation. . . In that portion of the empire to which it more particularly applies, it cannot but be received as a proof of the disposition of the Legislature to adopt all measures calculated to advance the interests of Ireland."

The Ordnance Survey of Ireland is Begun.—Armed with the authority of Parliament, the Board of Ordnance, under the Duke of Wellington, took immediate steps to commence the 6-inch survey of Ireland. But, already, in 1824, Colby had been over in Ireland, " to acquire a general idea of the country, and to seek a proper place for the measurement of a new base line." For this purpose Colby chose a site in County Londonderry on the eastern shore of Lough Foyle. The base was not measured until 1827-28.

Meanwhile, the triangulation was started. Whilst the trigonometrical work in the south-west of Scotland had been in progress, various hills in Ireland had been marked by signals and were linked up, by intersection, to the Scottish hills. These hill stations extended from the Mourne Mountains in County Down to Malin Head in Donegal, along some hundred-and-fifty miles of the north-east coast of Ireland. Of the hills used, Colby particularly mentions the importance of Divis, near Belfast, " the triangles of which it is the apex cover a space of about one hundred-and-thirty miles in one direction and about eighty miles in the other—no less than two hundred Trigonometrical Points were observed from it." In 1825 an accurate survey was made of the level stretch of ground on which the Lough Foyle base was, later on, measured.

Colby's first report to the Board of Ordnance on the General Survey of Ireland is dated 2nd February, 1826. In this he states that the officers employed on the six-inch survey of Ireland were supplied, in the beginning of the summer of 1825, with trigonometrical distances computed from observations made at the stations in Scotland, in order that no delay in the detail survey might occur. In this report he mentions Drummond's two inventions, namely, the heliostat and the limelight.

" The first is a Solar Reflector so ingeniously contrived that a soldier is capable of directing it with certainty and facility. . . The first [trial] made with the Solar Reflector was on the Divis, to be observed from Knock Layd, a distance of about forty miles. At this distance it was brilliantly seen with the naked eye at a time when the mass of the mountain was barely visible. . . Some notion of the light given by the

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lamp may be formed from the circumstance of its appearing more brilliant to the naked eye at the distance of upwards of sixty-six miles [from Slieve Snacht in Inishowen] than another lamp placed at a distance of about fifteen miles . . . the latter being of the description commonly used in lighthouses."

"To complete these trials and to furnish the necessary distances for the local Survey, the Officers and Men continued encamped on Mountains from 1,500 to 2,000 feet above the level of the sea, till towards the latter end of November and beginning of December, and much praise is due to them for the willingness with which they endured the personal inconveniences of exposure on those high situations at that inclement season of the year."

Formation of the Survey Companies.—Until the year 1825 most of the manual labour required in the operations of the triangulation had been supplied by detachments of Artillerymen. This employment of soldiers had been fully justified, both on the score of cheapness and on account of the steadiness imparted to the survey by Army discipline. Colby, when faced with the problem of organising the Ordnance Survey of Ireland, was satisfied that he could not do better than employ soldiers, even more freely, in this new extension of the work. He says :—

"When this Survey was proposed, a large portion of the Engineer Corps was unemployed, and I conceived that the whole of the soldiers in the Corps of Sappers had gone through a course of practical geometry, etc., under Colonel Pasley at Chatham. It appeared a regular Military Body might be formed from these sources, who would soon become capable of executing the greater part of the work, and that the deficiencies might readily be supplied as occasion required. The formation of this Military Body from the Corps of Engineers and Sappers during a period of profound peace, when few adequate objects were presented for the exertion of those peculiar talents which fit them for the duties expected in time of war, seemed to me to possess great advantages with regard to the Corps themselves."

Colby is here talking of the two Corps of Officers of the Royal Engineers, and of the men of the Royal Sappers and Miners, then distinct bodies. He goes on to say that :—

"As far as regarded the advancement of the Survey itself, two circumstances seemed in favour of this arrangement ; the one the unity of the system and facility of direction arising from military discipline, and the other the nature of the information already attained by the officers and soldiers. . . By the Military Body the whole of the work will be performed according to regular instructions, and it is probable that every part will be executed with equal accuracy, at least the instructions are so devised that the work itself will afford facilities by which its errors, if any, may readily be detected and traced to their sources. . . After the Military Body has acquired experience it will also have the further advantage of carrying on the work with much greater celerity than it could have been carried on by the hire of Surveyors."

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The Duke of Wellington approved of Colby's scheme, and Colby was given a free hand to select officers and men; his only difficulties with regard to the officers being his want of acquaintance amongst the officers and the smallness of the Corps itself. With regard to the men, it was found that those soldiers of the Corps of Royal Sappers and Miners who could read and write, and had passed through the course of practical geometry at Chatham, proved excellent material for the new companies. But it was also found that so many men had been enlisted in the Corps who could neither read nor write, that the formation of the three companies authorised was delayed. Colby remarks that "the Artillery recruit very much in Scotland and the North of England, where the spread of education is much greater than it is in South Britain. Twenty-four years' experience on the mountains has enabled me to observe that the Artillery are generally intelligent, hard-working men and good, obedient, trustworthy soldiers." This latter remark was made with reference to an idea, not carried out, that the personnel of the Survey Companies might be filled up by transfers of Artillerymen.

Colby gives the following *Chronological View* of the formation of the Survey Companies:—

"1824. 1. August 28th.—I proposed the first Surveying Company officially.

2. September 22nd.—Surveying Company ordered. [13th Coy. R.E.]

3. November 26th.—First detachment of Surveying Company went to Chatham.

4. December 8th.—Surveying Company complete at Chatham.

1825. 5. March 18th and 31st.—Surveying Company went to Ireland.

6. February 16th.—Second Surveying Company began to assemble at Chatham. [14th Coy. R.E.]

7. July 16th.—Part of Second Surveying Company sent to Ireland. N.B.—The greater part of these were taken to supply the place of the Artillery on the Trigonometrical Survey.

8. December 27th.—Another part of the Second Surveying Company sent to Ireland. N.B.—It is still incomplete. (January 30th, 1826.)

9. September 10th.—Third Surveying Company ordered. [16th Coy. R.E.]

Throughout this period of the formation of the Survey Companies, Colby was in constant correspondence with Col. Pasley, who commanded the School of Military Engineering at Chatham. These two officers were always on excellent terms, and Pasley materially helped in the creation of the new military establishments of the Survey. He wrote to Colby on the 19th February, 1825:—

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"I have received a number of Men, who, I think, will form a very good Nucleus to the 2nd Surveying Company, which will be numbered the 14th. I have to request that a Captain and a First Lieutenant may be named for it as soon as possible. Dalton has exerted himself so much in forming the 13th that I expect that much emulation will arise, and the Duty of Instruction of the 14th Company will be well done, when Officers are appointed. . . . I will do everything to forward the Service of the 14th Company, but the sooner the Permanent Officers join the better."

On the 23rd July, he writes to Colby:—

"I take this opportunity of requesting that you will restore their Arms to the men of the 13th Company. From my experience in the Military Duties of the Corps, I am quite persuaded that the Men of that Company will be ruined as Soldiers, and lose not only their own *Esprit de Corps*, but will be disgraced, or say *completely lowered*, in public estimation' unless their arms be restored to them. . . The 13th and 14th Companies . . . . are each organised military bodies; and if deprived of their arms, I am sure that the evil consequences I prognosticate will follow.',

And again, in August, 1825, Colby having made some objections as to the political capital that might be made out of soldiers under arms being engaged on the work, Pasley replies:—

"Peaceably employed in surveying . . it must be quite impossible for them to come in collision with the People of the Country at all. I sincerely hope that you will take an early opportunity of restoring their Arms."

In this controversy it cannot be doubted that Pasley was right and Colby was wrong. Colby seems to have admitted the error; anyway, the men of the Survey Companies have always had their arms like other soldiers.

Some Details of the Administration.—On the 7th April, 1826, the total strength of the Survey establishment was 203, made up of 28 officers, four candidates and cadets, 106 sappers and miners, and 65 labourers. The total expenditure for the year 1825 was £16,218, and for the half-year, January-June, 1826, £9,560. We may say a strength of 200 and an annual cost of about £20,000. The rates of pay were low, "inferior assistants," or labourers, to drag the chain, receiving from 9d. to 2s. a day; the 9d. rate being probably given to boys on probation. There were originally no superior civilian assistants, except one clerk on 2s. 8d., and two draughtsmen on 4s. a day. The officers and sappers received survey pay in addition to regimental pay. The field work was concentrated in the north of Ireland; at the end of 1826 there was a Headquarter Division at Mountjoy, Phœnix Park, Dublin, under Major W. Reid (afterwards Sir William Reid, Governor of Malta); and five survey districts at Belfast, Coleraine, Londonderry, Maghera and Lisburn, under Captains T. F. Lancey, P.

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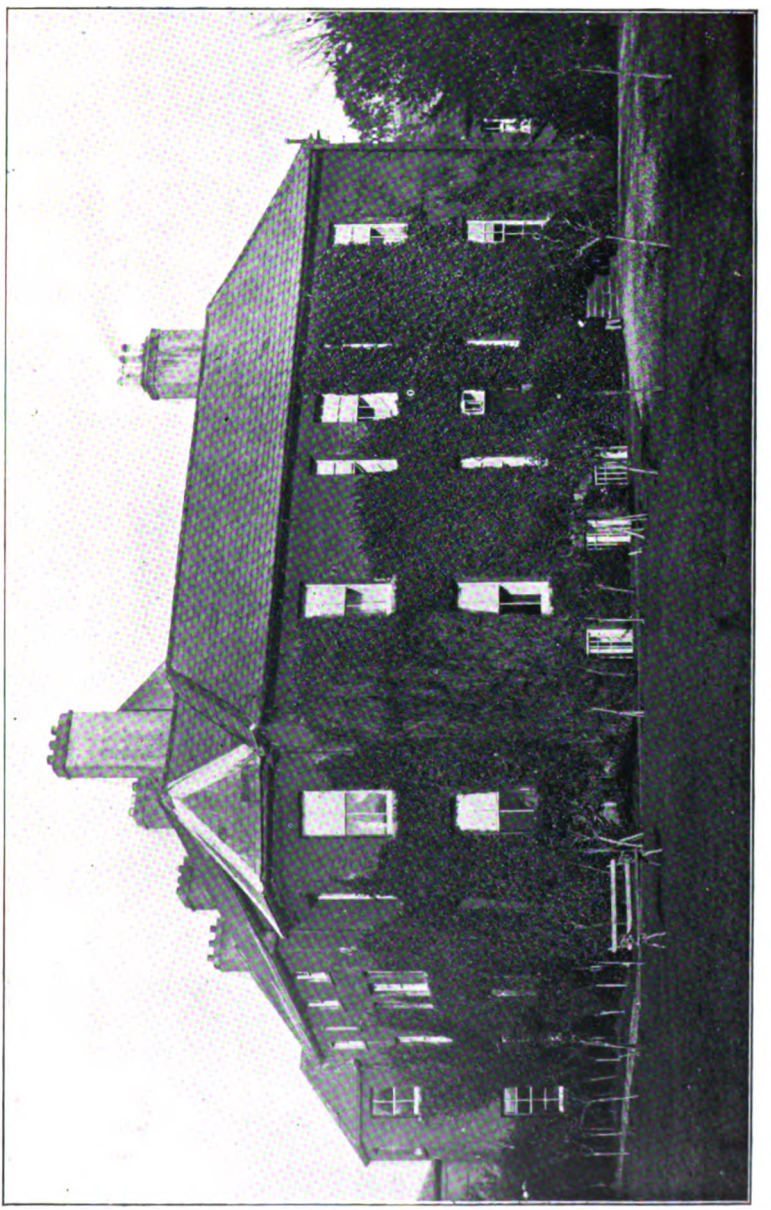

Mountjoy, Phœnix Park, Dublin.
Headquarters of the Ordnance Survey of Ireland, from 1825.

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A portion of the
Down Survey of Co. Kildare 1655.

Scale:- 80 Irish Perches to 1 Inch or 3·2 Inches to 1 English Mile

Over-printed with the modern 6 Inch Map reduced to the same scale

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Yule, M. A. Waters, C. Wright, and Lt. English, respectively. J. E. Portlock, who some thirty years later wrote the *Memoir of General Colby*, was among the subalterns. In addition to the officers at Mountjoy and in the five districts, we must reckon those employed on the triangulation—Drummond, Larcom, James and others. There were five Artillery subalterns on the strength of the Survey.

Mountjoy House.—An admirable house was selected as the headquarters of the Ordnance Survey of Ireland. Mountjoy stands in Phoenix Park, in sixteen acres of its own grounds. It is a substantial comfortable house, just the kind of house that one might expect a well-to-do Irish gentleman to have built in the old days. It was, as a fact, built about 1728, by the Rt. Hon. Luke Gardiner, when he was Castleknock Keeper of Phoenix Park. His grandson became Lord Mountjoy, and was killed in the rising of 1798, when Colonel of the Dublin regiment. Musgrave, in his *Rebellions in Ireland* says that Mountjoy "had the gentlest manners, and the mildest affections, warm and sincere in friendship, and so benevolent and humane that he never harboured revenge." It is said that Mountjoy added a theatre to the house in 1778, in which *Macbeth* was acted. At the end of the eighteenth century the house was bought by the Government for the Secretary at War.

By 1812 the house had been turned into a barrack and the land adjoining was known as the Barrack Demesne. In 1825 the Board of Ordnance handed it over to the Ordnance Survey as the headquarters of the Survey of Ireland. Major Reid seems to have lived there; and certainly, in after years, the house was the dwelling place of successive officers, who had, under the Director, charge of the Irish Survey. Only part was used as a dwelling house. The rest was converted into offices for the various indoor operations of the survey; and, year, by year, other buildings grew up round it; barracks for the men, workshops, stores, machine shops, and so on, until it became a very complete establishment. It remained under the Director of the Ordnance Survey of the United Kingdom until 1st April, 1922, when the establishment at Mountjoy, with the rest of the Survey of the Irish Free State, was handed over to the Government of that State. The value of the buildings and machinery was then estimated at about £160,000.

Many an old Ordnance Survey official will retain kindly memories of the big, red house and the survey buildings amongst the trees, the home for a hundred years of much good work and loyal service.

Boundaries.—The chief and original object of the Ordnance Survey of Ireland was the marking exactly on paper the boundaries of counties, baronies, parishes and townlands, and the ascertainment of the areas of these divisions. From the beginning, Colby

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refused to take any responsibility for the determination of the situation of these boundaries on the ground, only promising to survey them accurately when pointed out. The duty of ascertaining the boundaries of the ground fell to the lot of a Boundary Department, under Mr. Richard Griffith. Colby's early reports are full of complaints as to the way in which the Boundary Department carried out its duties. He says, in February, 1827, that that Department was "in a peculiarly defective state, and a great deal of time was lost through the want of proper Boundary Surveyors"; also, that he "found persons had been appointed as Boundary Surveyors who did not consider the duties they had to perform as of any great importance."

Some of the Meresmen, "being ignorant of the Boundaries, went round with my officers, enquiring of the inhabitants as they went along . . and the boundaries were frequently pointed out wrong"; and again, "it is my virtual dependence on the progress, and correctness, of the Demarcation Department that renders it so extremely difficult for me to calculate the time required for the Survey." But matters improved, and, in February, 1828, Colby reported that, "the Boundary Department, under the direction of the Irish Government, is becoming much more effective, and is now nearly adequate to the present rate of progress of the Ordnance Survey." But it can hardly be said that Colby and Griffith worked altogether amicably together, even after this date. Thus, in a letter written by Griffith to Colby, and dated Sligo, September 26th, 1828, there occurs this passage:—

"According to the Arrangement entered into between the Irish Government and Sir Jas. Smith, I am only to be six months in advance of the Ordnance. Will Capt. Waters undertake to complete the survey of the whole of his present district within six months after November next, if not the arrangement will have been broken through by him, and any casualty among the meresmen or expense incurred by calling back the boundary surveyors from distant parts subsequently to that period must be charged to the Ordnance.

With regard to the allied question of the marking of property boundaries, the principle of the Ordnance Survey has always been to show any features visible on the ground, from which such boundaries may be measured or inferred, but not, except in the case of administrative divisions, to mark ideal, or invisible, lines. In a draft of a memorandum written by Colby about this period, it is stated that:—

"If any boundaries are to be inserted, those boundaries should be first rendered distinctly visible in the country by the erection of well defined marks of a nature sufficiently permanent to be appealed to in case the accuracy of the survey should be hereafter called in question. And if the Ordnance make a faithful representation of what can be seen

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in the country without inserting invisible boundaries . . . they will perform all that can be required of them."

It is a good, practical rule, not, in general, to show invisible boundaries, and it resulted from this rule that property boundaries, as such, are not shown at all. But since property boundaries depend on fences, walls, hedges and similar visible objects, there is no difficulty in using Ordnance maps as property maps, indeed they are universally used for this purpose; although the hedge or fence may not be the boundary proper, which often, indeed usually, runs a few feet distant from, and parallel to, it.

Colby's Intention with Regard to the Civil Staff.—Colby intended to form a military department, in which all the principal operations out-of-doors, and most of those in the office, would be carried out by soldiers. He contemplated, in addition to the officers and the survey companies, an establishment of labourers to drag the chain and do other work of a purely manual nature; but he had also in view an establishment of a few civilian engravers and some civilian draughtsmen to supplement the military draughtsmen. He complains, in a report written in February, 1828, that when he was necessarily away in England a kind of discretionary power was allowed to the branch office of the Board of Ordnance in Ireland, and that things were done in his absence of which he disapproved. He says,

"If no such Board [the Irish branch] existed, I feel convinced that the Irish Survey would not have been suddenly overwhelmed in the winter of 1826-27 with an influx of uninstructed civilians. And the disorganization and expense attendant on that violent local measure would have been saved. When I visited the Districts in October, 1826, it was observed to me that draughtsmen were wanted, and I certainly did desire the District Officer to look out for a few men who could assist in drawing. But how was this want supplied? Advertisements were put in all papers, unknown to me, and a great many persons were engaged who had everything to learn. . . That this measure, so far as it produced for the Survey a few Civil Draughtsmen, was beneficial there can be no doubt, but thus far it was my intention from the very commencement of the Survey to adopt it."

The Royal Sappers and Miners.—In the same report Colby writes:—

"On the whole the Royal Sappers and Miners have proved a highly efficient force, and it is much to be regretted that they are not more immediately identified with their Officers by being called Engineers instead of Sappers, etc. They are deprived of the encouragement of being mentioned in Public Despatches by having no officers of the same name. And it cannot be doubted but the means of obtaining good recruits is greatly diminished by this apparently trivial circumstance of having to bear a long and obscure name which has no reference to the greater part of their duties.

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Pasley says in a letter to Colby :—

"The different name has been and is the greatest possible impediment to the Recruiting of the Corps. In fact it deters the men most qualified for our Service from entering it. I wish to God, that vile *labour-like* name could be abolished."

The change of name advocated by Colby, and even earlier by Pasley, was not sanctioned until 1856. In the *London Gazette* for the 17th October, in that year, appeared the following notification :—

"The Queen has been graciously pleased to direct, that the corps of royal sappers and miners shall henceforward be denominated the corps of royal engineers, and form one body with the existing corps of royal engineers."*

The Lough Foyle Base, 1827-28.—As we have seen, bases, in the early operations of the Survey, were measured with wooden rods, or glass tubes, or steel chains. It now became necessary for Colby to consider how he should measure a base in Ireland; for it was certain that a new base was required, not only on account of the distance of the Irish work from any of the previously measured bases, but also because it was desirable to stiffen the old triangulation and to attempt a higher degree of precision.

In 1825 Colby hit upon the idea of compensation bars; the reason for adopting such a contrivance being that, in the measurement of a length with a metal chain or bar, an ever-present difficulty is the impossibility of ascertaining accurately what the temperature of the metal is. Colby, therefore, thought that the principle of compensation, which had long been in use in the construction of clocks, might be applied to the measurement of bases. As worked out by Colby and Drummond the base apparatus was thus designed.

Two bars, one of brass and one of iron, were laid parallel and close to each other. The bars were firmly connected at the centre, and were free to expand or contract from, or to, this point. Now, approximately, at ordinary temperatures, brass will expand .00001 of its length for every increase of 1° F.; and, similarly, iron will expand .0000065 of its length; so that the expansion of brass to iron is approximately as 100 to 65. If then, the ends of the bars are firmly connected by metal tongues, fixed to the bars by pivots, so as to allow the bar to expand, there will be a point on each tongue which does not move with reference to the central points of the bars. The immovable point will be about 100 units from the centre line of the brass bar, and 65 units from the centre line of the iron bar, the actual distances depending upon the space between the centre lines of the bars.

* *History of the Royal Sappers and Miners*, by T. W. J. Connolly, Vol. II., p. 492.

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Each bar of brass, and of iron, was 10 feet 1½ inches long, ½ inch broad and 1½ inches deep, and the bars were placed 1⅛ inch apart, and firmly connected at their centres. The metal tongues connecting the ends were about 6 inches long, and on a silver pin at the extremity of each, was marked the compensation point. With the figures given, it will be seen that the compensation point was about 3 inches outside the iron bar.

There were six of these compound bars; in the field they were placed on trestles, with elaborate arrangements for aligning and levelling. The bars were placed end to end, but not touching, and the distances between the compensation points were fixed by two microscopes attached to the cases which held the bars; the two microscopes lying parallel to each other and connected together in such a manner that the outer foci of their object glasses were compensated points exactly six inches apart.

The authoritative account of this apparatus, and of the measurement of Lough Foyle Base, and of the many experiments necessary to determine the expansions of the metals and the positions of the compensation points, and of the calculations for the definitive value of the length of the base itself, will be found in *An account of the Measurement of the Lough Foyle Base*, by Captain William Yolland, R.E. This account was not published until 1847, about 20 years after the measurement was made, and just at the time that Colby was retiring from the Survey. The lateness of the publication of this account is evidence of the reluctance which was, apparently, always felt by Colby to publish anything connected with the work; and this reluctance may have been partly due to his remembrance of the refusal of the Board of Ordnance in Mudge's time, in 1811, to publish any more reports of the work of the Trigonometrical Survey.

The Measurement.—The officers employed upon the measurement of the Lough Foyle Base were Lt.-Col. Colby, Captain Pringle, and Lieutenants Drummond, Henderson, Murphy and Mould, all of the Royal Engineers. About half the soldiers working under them were Artillerymen, and about half Sappers and Miners; the largest number employed at any one time (in October, 1827) consisting of 27 Artillerymen, 25 Sappers and three civilian labourers.

The site selected by Colby was a stretch of ground along the eastern shore of Lough Foyle, at an average height of 18 feet above mean sea level. The chief difficulty to be contended with was the crossing of the River Roe at about the middle of the line. The length was nearly eight miles. Drummond writes on the 24th June, 1827:—" The encampment is by the side of Mr. Gage's park wall, near the Roe."

The actual measurement began on the 6th September, 1827;

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this was continued until the 25th October. Work was resumed on the 7th July, 1828; continued until the 25th of the same month, when it was suspended to avoid damage to the crops. It was again resumed on the 13th September and completed on the 20th November, 1828. The number of days spent in measuring was 95, and the average daily progress was about 460 feet. Sir John Herschel and Babbage visited the work, and the former made a sketch showing the method of measurement.

The Standards of Length.—Two new standard wrought iron bars were made by Messrs. Troughton and Simms in 1826-27. These bars still exist, and are 10 feet long between the measuring dots. Each bar is 1.45 inches broad and 2.5 inches deep. The distance of 10 feet was marked when each bar was at a temperature of 62° F. These bars are known as O_1 and O_2; O_1 was sent to Lough Foyle to enable comparisons to be made with it; and O_2 was retained in the Tower of London, in case any accident might happen to the first bar.

Yolland quotes no fewer than eleven other bars and scales which, up to 1846, had been used as standards in Great Britain, and had been compared by the Ordnance Survey. These include Bird's Standard Yard of 1760, which was destroyed in the fire which consumed the Houses of Parliament; the Indian 10 feet iron standard bar B, the Cape 10 feet iron standard bar B, Roy's brass scale, Ramsden's 20 feet triangular iron bar. Simms' 10 feet iron bar, and others.

Accuracy of the Base.—The length of the Lough Foyle Base, in terms of feet of O_1, was found to be 41640.8873 feet. This base has never been re-measured, so that there is no direct test of its accuracy. But an indirect test exists. The net-work of the Principal Triangulation connects the Lough Foyle Base with the Salisbury Plain Base, which was measured in 1849 with the same apparatus. If we assume that the latter base is errorless, the length of the former base, calculated through the triangulation, differs from the measured length by 5 inches. Clarke, in his reduction of 1858, took the errors of these bases to be inversely as the square roots of their lengths, and the discrepancy of the measured, as compared with the calculated value, of the Lough Foyle Base is, then, about $2\frac{1}{2}$ inches.

On the lengths of these two admirable bases, given in feet of the bar O_1, depend all Ordnance Survey measurements to this day.

Some Letters about the Base.—Capt. Pringle to Colby, Trig. Survey Camp, Magilligan, 13th September, 1827:—

"The severe gale which we experienced on Sunday morning and which is represented by the residents on the plain as what may be frequently

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expected to occur in the course of the Autumn, has convinced me and the Officers employed on this duty of the expediency, or rather, necessity of being enabled to augment the night guard. . . The guard cannot be trusted to the civil labourers whom we can hire for day work. . . . The Artillerymen here have conducted themselves with the greatest regularity and are particularly fit for the duties required."

In another letter he asks for a corporal or sergeant and 8 or 12 Artillerymen.

" For as the season advances storms will be frequent." " Drummond and Murphy were out at six this morning, Henderson and I relieved them at eight, but still only two moves . . . 12 or 15 Artillerymen would be only so many shillings a day."

Magilligan Camp, 3rd July, 1828 :—

" The Detachment of Artillery, 13 men, have just arrived. . . . Corporal Young and the other men who were with us last year have not arrived. Pray order them without delay . . otherwise we shall have all the annoyance and delays of teaching to repeat. Lieut. Murphy we have heard nothing of, and are anxious about him. Lieut. Henderson writes he is to be here on Sunday, and Capt. Waters that Lieut. Mould is to come when he has finished his station. Lieut. Drummond has finished all the comparisons and made the adjustments, and has also set up marks on the line, so we are quite ready to commence when two more Officers join. . . You took . . a memorandum to order another Smith from the party in the hills, which I hope you have done, as we shall have a great deal of Smith's work.

" We have been examining the Roe and considering the easiest mode to measure across it. Driving piles appears on the whole the best, so I shall order piles, etc., from Derry. We are experimenting with a frame filled with sand bags, or stones." . . . .

On the 16th July, 1828 :—

" We now hope to pass the Roe the end of this week. We have been pushing very hard to do so, commencing at 3 a.m., as the tides will answer best—being high water at mid-day. . . There is only about a quarter mile beyond the Roe until we come to continued crops. . . I have been too busy to think of the Geological Memoranda."

26th July, 1828 :—

" Lieuts. Henderson and Drummond have been advocating the policy of buying the Crops—this season is, no doubt, the most advantageous for measuring, morning and evening. But I think the appearance of what would be judged unnecessary damage, is much against it. . . . The men are employed now in drawing up the piles in the Roe. . . The party of Artillery . . will march for Charlemont on Tuesday. . . P.S.—Sergeant Sim has come to tell me that the men would rather remain here even without pay than go to Charlemont and [I] propose to retain them on half-pay /6, if we commence in six weeks."

In a letter to the Board of Ordnance written in February, 1828, with reference to the possible employment of Captain Pringle on

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temporary duty in Canada, Colby asks that he may not "be deprived of the services of that excellent officer" beyond the period which might be necessary.

From Lieut. Hastings Murphy, R.E., to Colby, Magilligan Camp, 18th July, 1828:—

"I left my calculations, etc., with Portlock. . . Portlock was very well and in good spirits, but had seen nothing to the South, except Ardan Erin. . . I remained with them about four hours on Friday and pushed on to Enniskillen, and here next night. We are getting on famously, having last night reached the Roe; if this day were not so very windy we should be across this evening. We have been at work about 16 hours a day."

Murphy to Colby, Ballykelly Camp, 12th November, 1828:—

"I hasten to reply to your kind enquiries after our friend Drummond. I have just been to see him in his comfortable quarters at the Glebe, and am happy to say he is doing very well, having sat up to-day for three hours and eaten part of a chicken. . . Certainly he gains strength every hour compared with the extreme state of debility to which he had been reduced by fever, bleeding (30 ounces at once), medicines, etc., etc. . . Dr. Dice, of Newtown, has been his physician . . and bled him very freely at first, and said it saved him from a bad typhus or rheumatic fever or both."

The writer of these two letters, Lieut. Murphy, did much excellent work on the Ordnance Survey, not only in the measurement of the Lough Foyle Base, but also in the observation of angles on Divis, and at other stations, and in the comparison of standards. He left the Survey in 1834 to accompany Colonel Chesney's expedition, which was to examine into the possibility of establishing communication with India by way of the Euphrates. He died at Bussora in July of that year.

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DAM CONSTRUCTION IN TIDAL CREEKS.

(Continued.)

By MAJOR E. ST. G. KIRKE, D.S.O., R.E.

IN the December issue of 1923, an article under the above title was published in this Journal describing the construction of two monolithic concrete dams near Shoeburyness, both of which were built upon open foundations by direct labour.

These dams, marked C and D on sketch map, were part of a scheme to reclaim New England Island (which the sea broke into 28 years ago) with the object of making a reinforced concrete road direct from the mainland to Foulness Island. The latter is a War Department estate, and hitherto the only access to it was by boat, or along the "Broomway," a track over the sands, available at low tide. This use of the sands was a constant source of interference with the Artillery Ranges.

Two views of the reclaimed island will be found in Photos 11 and 12, before and after reclamation. The trestle bridge, which is shown in them had to be made for the conveyance of man and materials on to Foulness. It is 2,000-ft. long, and has been the innocent cause of the purchase of two or three hundred bicycles by the islanders, many of whom had never previously visited the mainland.

A third dam has now been constructed, known as "B" dam, upon subaqueous foundations, which were rendered necessary by the fact that the tide never entirely receded from the site. The essential difference between the construction of dams in creeks, and those to control rivers, was well illustrated in the case of this dam. This difference lies in the fact that the former are exposed during construction to the full attack of the sea twice every twenty-four hours; whereas the latter are not fully stressed until months after the work is complete.

In the previous article the considerations governing the design of the various dams were given, but it may perhaps be as well to give a short summary of them.

In the case of "C" and "D" dams the tide could fall away on the sea side down to the levels of 2.66 and 4.3-ft. above Ordnance Datum respectively, and drain away altogether towards the river Crouch on the land side. The above, therefore, were the maximum heights to which the dams could impound water between themselves and the "Broomway." These dams could thus be raised. course by course, to the requisite height.

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New England Island was flooded completely at spring tides to a depth of four feet, by water entering the creek from the Crouch, and thus formed a reservoir of very great extent. The problem at "B" dam, therefore, resolved itself into making provision for shutting out the sea on one tide. Had it been raised course by course like the other two dams, it would have impounded this water. Another consideration was the possibility of a "freak" tide occurring, two feet higher than high springs. These exceptional tides are caused by strong N.N.W. winds in the North Sea, S.W. gales in the Channel, heavy rainfall in the Thames Valley, or easterly gales occurring at full moon. It was a tide of this kind which originally broke into the island in 1897, since when it has remained derelict, and a similar tide occurred a couple of years ago, rising to a level of 14.3-ft. above O.D.

Very much higher levels than this have been recorded further up the Thames, owing to the water being banked up as the width of the river decreases, and in 1876-77 three tides rose to 16.75-ft., flooding large districts around London. In the Medway, too, heights of nearly 16-ft. above O.D. have been recorded at Rochester Bridge.

So far as "B" dam was concerned, a tide of 14 feet would have taken the dam in reverse, if it occurred before the broken sea-walls of New England were raised to full height, 15.5-ft. It was, therefore, necessary to leave the water a way of escape, until the walls were repaired.

Design.

The extent to which the waterway in these creeks could be restricted without rapid scour taking place (in the absence of heavy stone or chalk pitching) was found to be about half the original area, and this governed the amount which had to be left open until the time for closing it permanently arrived.

Several methods of closing the waterway suggested themselves, such as lock gates; sluice gates sliding in vertical grooves; or wooden shutters hinged at the top, on the principle of the ordinary tidal flap valve, but propped open until required. Of these, the lock gates would require heavy piers to carry them, owing to the lateral thrust imposed; the gates sliding in vertical grooves would require elaborate operating gear; whereas the flap shutters, while probably not so watertight, would open of themselves, should an exceptional tide take them in reverse. Further, they were the cheapest, and half the weight of corresponding lock gates with their heavy hinge-posts, mitre-posts, and waling.

The piers to carry the flaps could either be of reinforced concrete, or steel structures of suitable design. The latter would have been quicker to erect, but the greater weight and stability of the former decided in their favour.

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The foundations for the piers raised several interesting points. To enable work to be carried on every day it was desirable for them to be above low water level on neap tides, *i.e.*, about —2.5-ft. O.D. On the other hand, it was not possible to block up so much of the tide-way, while piling was in hand, without excessive scour taking place. The level —3.5-ft. was fixed upon as a compromise.

A curtain wall of sheet piling was essential to prevent underscour or infiltration, and use was made of 8-in. "Simplex" interlocking piles which had been bought for the original scheme for damming the creeks, referred to in the previous article. (This was to shut the sea out by a wall of piles so that an earthen dam could be built behind it. Its disadvantages were discussed.)

A second curtain of piles was driven on the inner side of the dam, so as to protect the foundations from scour during construction, and as an additional safeguard against infiltration.

Considerations of space have prevented a section of this design being given, but the pile line shown in Figs. 13 and 14, driven down to 19.5 ft. below O.D. is the front pile line of the first design.

Aerial Cableway.

For carrying the hammer to drive these piles across the creek, an ordinary gantry was discarded in favour of an aerial cableway, owing to the latter being so much quicker to erect. This cableway appears in most of the photographs. The legs of the shears supporting it were of 10-in. x 10-in. pine, 50-ft. long, bolted together at the top and rigidly connected at the bottom, so that they could be traversed laterally across the site of the dam. This method was safer than the usual luffing gear, having regard to the unskilled nature of the labour employed.

Two 3-in. steel cables were used to span the creek, in place of one of larger circumference, as they were in stock. They had a breaking strain of 18 tons each. At the top of the shears they ran over a cast iron bearing plate and were anchored to 18-in. x 18-in. timbers, 12-ft. long, buried 8-ft. into the ground. They were adjusted by two differential tackles on the Havengore end, so that a three-ton load would cause no more than a nine-ton strain in the two cables, giving a factor of safety of four.

Hoisting was done by a 2-in. steel cable running over the drum of a 2-ton petrol winch. This was also arranged to do the travelling in one direction, the other being worked by a hand winch on the far bank when slow speeds were required, and by a winding engine on the barge for running out stone and ballast.

Pile Driving.

Photo 1 shows the hammer resting on the pile which it is driving, and the ripple on the water indicates the pile line already driven

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between the barge and the piles appearing in the foreground. To minimise the loss of time caused by the tide rising, each pile was driven only so far as would allow of the next one being interlocked, which again was driven so as to remain six inches above water. All such piles partially driven were finished off as the tide receded.

The back line was driven first, so that the waterfall which it would cause in the ebb tide would wash out the mud from the site of the foundations. The water cushion formed by the impounded water prevented similar action taking place on flood tides.

The hammer used at first was a " No. 5 McKiernan-Terry Patent Double-acting Automatic Pile Hammer," supplied by the British Steel Piling Company, weighing 1,500-lbs. This would under normal circumstances drive two 8-in. " Simplex " piles at a time, with a delivery of about 300 blows per minute. In this instance, however, the accumulations of oyster shells in the creek offered such resistance that it sometimes failed to drive home even one; instead, crippling the head of the pile. For this reason 12-ft. piles were put into the back line, while a heavier hammer was obtained on hire from the same firm to drive the front line and the piles round the sluice pipe. This was a " No. 6 " weighing 2,900-lbs. and delivering about 200 blows a minute, which could drive three piles at a time most of the way. It nearly always succeeded in smashing a way for single piles through the oyster shells, but failed on a few occasions, and the piles were then levelled off with an oxy-acetylene cutter.

Steam for the hammer was provided by a boiler on the barge, which was kindly lent by the Royal Artillery. The maximum number of piles driven in the few hours allowed by the tide in one day was forty. Working at this speed, however, made it difficult to keep a really straight line, which was hard enough in any case when working from a swinging aerial, with a strong tide running in alternate directions. The wind, too, was frequently boisterous enough to move even the heavier hammer a couple of feet off the line. Another disadvantage of working from an aerial is that the hammer cannot develop its full blow, since a portion of its weight must be sacrificed in keeping it vertical. This must be set off against the extra speed of bringing it into action from an aerial instead of from a piling frame on a gantry.

The steam pressure used was 80-lbs. on the boiler, but 100-lbs. is recommended when the rest of the outfit will stand it.

The policy of keeping the pile line down to —3.5-ft. O.D. was amply vindicated as the far bank was approached. Even at this level the scour round the end kept pace with the pile-driving for a couple of days. However, by interlocking several piles

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above water level and driving down the shutter thus formed during neaps, and at half tide when the rush of water somewhat relaxed, the line was made good from bank to bank. If the line had been a foot higher, it is doubtful whether this would have been possible without recourse to chalk pitching. Chalk would have taken at least a fortnight to obtain and the sea would have had the extra time in which to develop a scour.

Both front and back pile lines were taken half way up each bank, where drop-walls could easily be excavated in the clay.

In the front pile line were incorporated special holed piles through which passed the bottom members of the reinforcing frames for the piers. To fix the frames rigidly into the piles, steel wedges were driven hard in with a 7-lb. hammer. These wedges also permitted slight adjustments in level. In addition, 1½-in. steel pins were driven through the bottom member outside the pile lines. This was the simplest way of fixing the reinforcement to the pile line, so as to prevent the piers overturning when the flaps were closed, but contained elements of weakness as will be seen later on. Single holed piles were driven in at 11-ft. intervals, as near the back lines as possible, to fix the back of the frames before they were embedded in the concrete floor. (It may be mentioned that 11-ft. intervals admitted the largest flaps which could conveniently be constructed and handled on the aerial.)

Four special tapered piles had to be put into the front line to correct for vertical, as the piles gradually inclined sideways towards the far bank owing to their free end offering less resistance to driving than that interlocked. These tapered piles were four inches wider at the bottom than at the top, and were made by cutting and riveting together two ordinary piles.

Pile-driving was carried on between 25th September, 1922, and 26th November, 1922, and again between 6th January, 1923, and 28th March, 1923. During these periods 1,003 piles were driven by 14 men, including the Military Foreman of Works, in 84 working days. The cost of driving both pile lines was somewhat less than an estimate received from a contractor for driving one, namely, £700.

Sluice Valve.

The 42-in. sluice for carrying off rainwater was placed at the Havengore end for convenience in construction and subsequent operation when the dam was completed. Two extra pile lines were driven underneath it as an additional safeguard against infiltration. A few X-piles were added in case it proved necessary to connect up further lines. The centre line of the sluice was placed slightly off the right angle, to lead the water draining out away from the bank

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With the pile-lines completed, it was possible to start on the foundations proper, and to put the sluice pipe into position. To convey concrete to the latter from the mixers, a narrow-gauge (2-ft.) line was run out over the sea-wall and supported on piers made of one yard cube concrete blocks. These blocks were taken out on the aerial and the piers placed at 15-ft. centres.

The piles in front of the flap-valve were driven down nearly to low water level, so that the compartment prepared for the foundations of the sluice would drain itself without pumping. The piles were not sufficiently watertight at this stage for the available pumps to keep the water down. This was primarily due to some of them not being long enough to be driven sufficiently far below a scour which had been caused by the steam barge remaining too long in one position during the early days of pile driving.

When the first length of pipe had been concreted in and the flap valve attached, the latter kept the water out and allowed an appreciably longer time for fixing the remainder before the rising tide stopped work.

The back line of piles opposite the sluice pipe was cut out by oxy-acetylene after the pipes had been concreted in. A clay cofferdam was built behind this section of piles, so that water could be pumped out while the cutting was in progress. This was cheaper than hiring the heavier hammer, for another fortnight, to drive the piles down to the level of the invert.

Foundations.

The general plan for making the subaqueous foundations was to fill up the space between the two pile-lines with ragstone and ballast to a level of —4.5-ft., and on the top of this to lay two-ft. of concrete into which the bottom member of the reinforcing frames would be embedded, the whole forming a floor on which to build the piers. The ragstone was then to be grouted up to form a homogeneous mass down to the floor of the creek.

The ragstone and ballast were run out on the aerial in bottom-emptying skips, holding over two tons, and dropped through the water at high tide when other work was stopped. The material thus deposited was levelled off at low tide in readiness for the concrete, which was tipped from the Decauville down a shoot. This concrete was protected from the ebbing tide by a wall of bags filled with clay, which ensured still water, and this was gradually displaced as concrete was pushed forward into it from the near side. (Photo 2.)

Pier Construction.

Before covering up the freshly deposited concrete with sailcloths and rails, etc., to protect it from the incoming tide, a wooden frame

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corresponding to the bottom of the pier-casings was let into it. The impression left in the concrete by this means can be seen in the foreground of Photo 2. This and Photo 3 also show the wooden and steel trestles which were carried forward on the aerial, as required, to support the Decauville for running out the concrete, ahead of the piers. The bottom members of the trestles straddled the pile lines, and rested upon them.

The reinforcing frames were made of old 60-lb. rails, which provided the necessary section of steel in a cheap form, and had the additional advantage of being very easily handled on the aerial and kept in place during concreting. A near view of one being embedded in concrete is given in Photo 2, and a still nearer view of the back member of a frame which has already been embedded.

In the best fortnightly tide-cycle four reinforcing frames were fixed and wedged into their holes in the piles, four piers were built, and the equivalent length of floor laid, namely, forty-four feet. The average was nearer three pier-units.

Photo 3 shows the piers half way across the creek, and the force of the returning tide rushing over the newly-deposited concrete in the floor just beyond the pier-casings.

These casings had to be made of something which would not float, and, for rapidity in assembling, of as few component parts as possible. Each side was, therefore, made as a complete unit consisting of "Simplex" piles laid horizontally, and kept in position between an 8-in. x 6in. timber on the inside, and a 60-lb. rail on the outside, bolted together. The function of the timber was to leave rebates and grooves in the concrete: on the front face for housing the flaps; in the middle to form a key for the concrete subsequently placed between the piers; and on the back to fix the casing for this concrete. For the bottom six feet of the casing an extra vertical support had to be given to the centre of the piles to prevent them bulging outwards under the weight of concrete when the casing was filled to the top. The two sides were held together by tie rods passing through slots in the piles, which were made of unequal length for convenience in fixing chain slings and were each handled as complete units on the aerial. Each side weighed approximately two and a half tons. The front and back faces were wooden shutters in two parts, held in position by wedges driven in behind the tie-rods. These various features are shown in Photo 4. Two sets of casings were sufficient, and were left in place a minimum of 48 hours after concreting.

Photo 4 also shows the last reinforced pier on the far bank being concreted, and the hopper of the shoot from which the floor concrete was poured, ahead of the piers.

The ragstone and ballast foundation, although a clear foot below the top of the pile-line, was thought to give the sea an opportunity

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of bursting the floor upwards when the flaps were closed if there were any leak between the concrete and the piles, or any undetected weakness in the floor. This danger was obviated by filling up the interstices with neat cement grout, and for this purpose wooden funnels were left in the floor, which passed down below the level of the concrete. A 2-inch rubber hose was used for grouting, which could be slipped over a pipe let into the bottom of an ordinary skip containing the grout. The outflow was controlled by a tapered wooden plug. Forty-five tons of cement were used in this operation.

The solid ends of the dam presented no particular features, and were quickly built. Where necessary, piers of yard-cube concrete blocks were made to support the Decauville. In some cases these blocks were incorporated in the dam, and in others they remained outside.

In order to ensure the flaps fitting well into the floor, sills were added, raising the height to —2.1-ft. These took some time to get in, as it was then well on into winter, and the water not low enough on spring tides, owing to the short working day, to allow of much work on the floor. When light permitted, this was best done between 5 and 9.30 a.m.

The wooden flaps to close the spaces between the piers had in the meantime been made up of elm, all ready to fit into their places. They were taken out on flat tops along the dam to their places, and picked up on the aerial by a single ring-bolt at the point of balance, a suggestion of one of the gangers. When thus suspended, they could easily be turned up from a horizontal to a vertical position and let down into place so that their hooks rested on the rails running between the piers provided for the purpose. This operation, including the fixing of keep-bolts to the hooks, took from five to ten minutes for each flap, and was done at low tide. The props were then added, and any adjustments noted. No more than six gates were placed in position in any one day, so that 14 spaces between the piers were available for the incoming tide. When it ebbed again, it swung open the flaps, which were once more picked up on the aerial, and the props allowed to drop into place.

As it turned out the twenty flaps could all have been run out and hung in position on one tide, but, in view of the possibility of a hitch occurring through any slight subsidence, it was safer to make certain of their all fitting correctly by trying each one in turn. Photo 5 shows the central portion of the dam with all the flaps propped open, and the last of the ebb running out.

On the first suitable day the flaps were let down into place, this operation taking an hour and twenty minutes. Back casings were fixed by passing tie-rods through them and the flaps, and securing them by cotters, which were much quicker to tighten and

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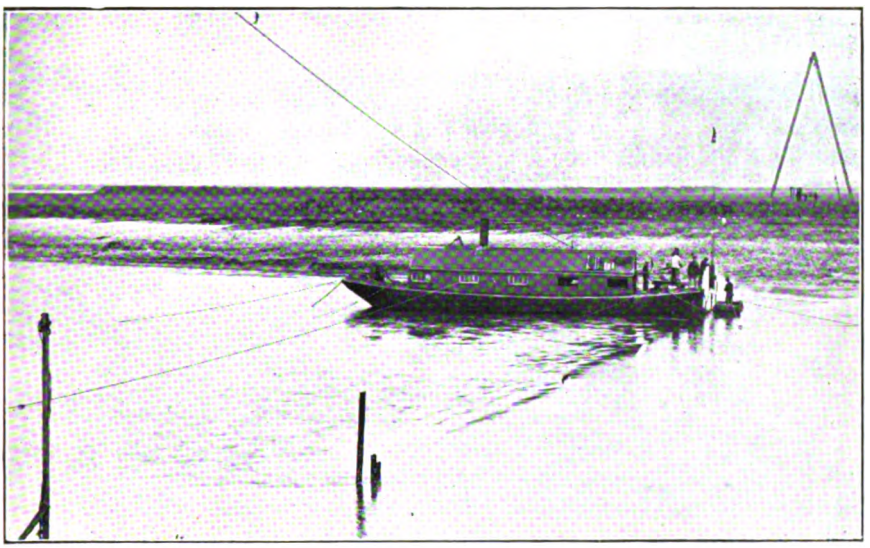

Photo 1.

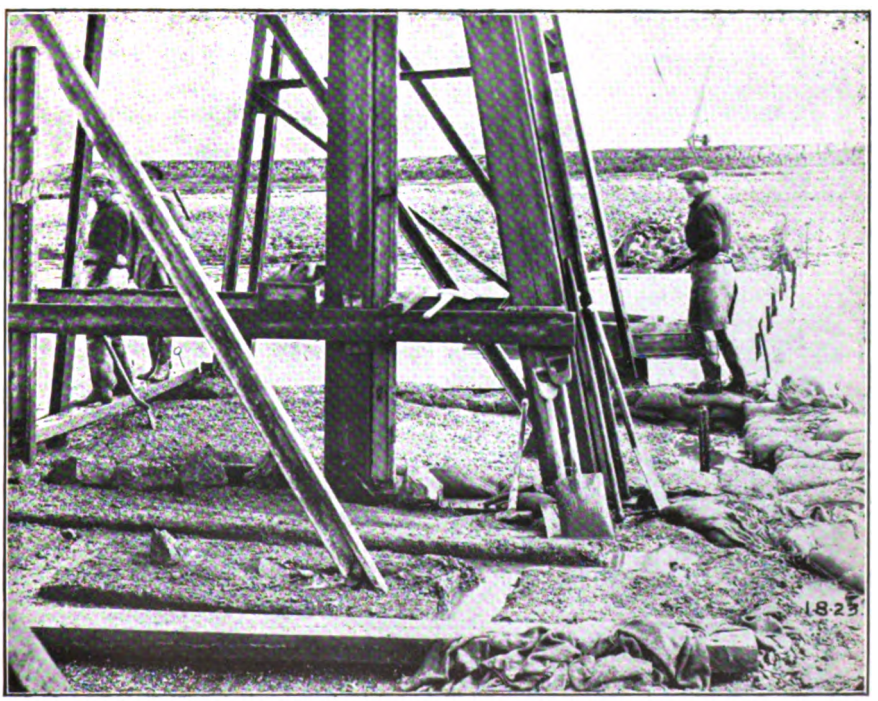

Photo 2.

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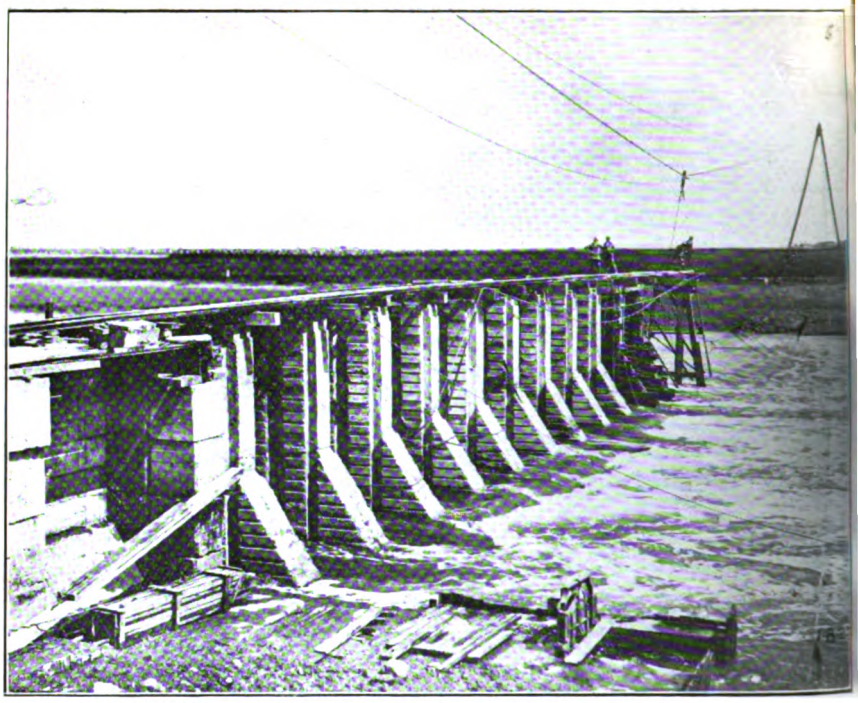

Photo 3.

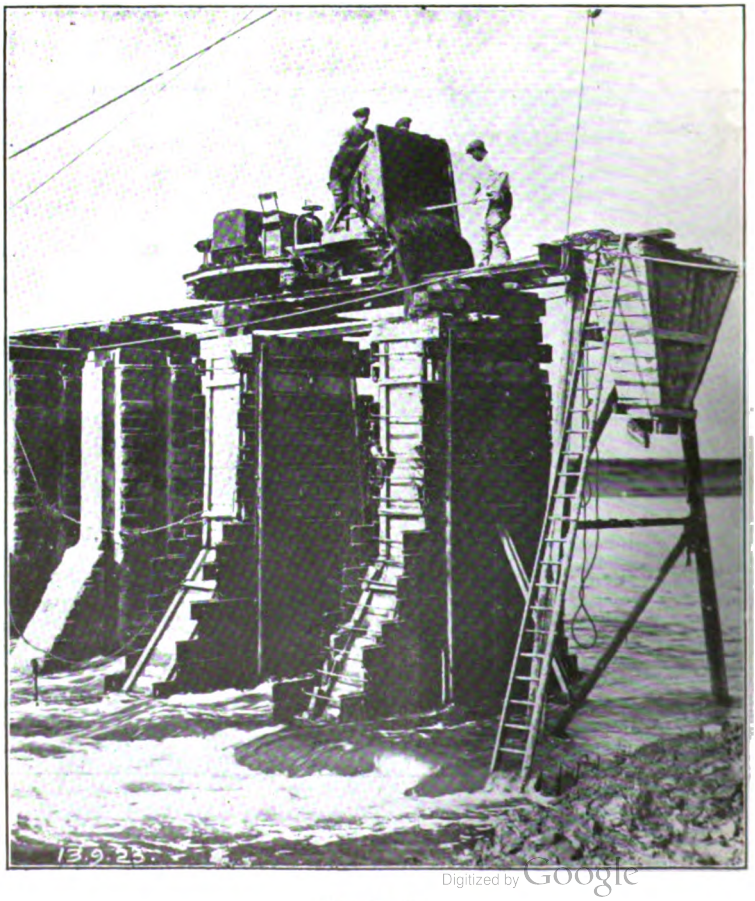

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Photo 4.

Photo 5.

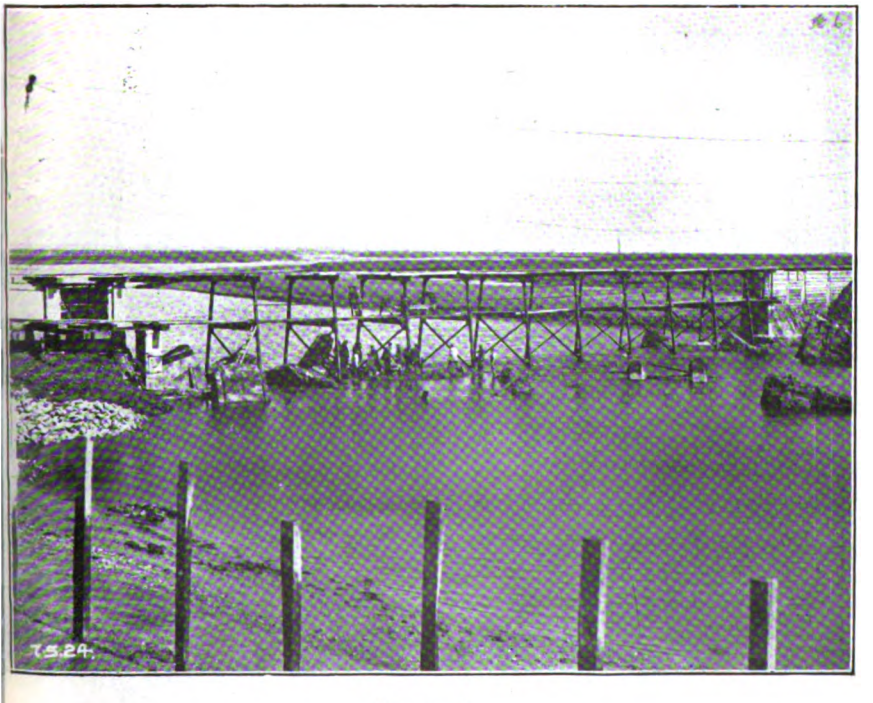

Photo 6.

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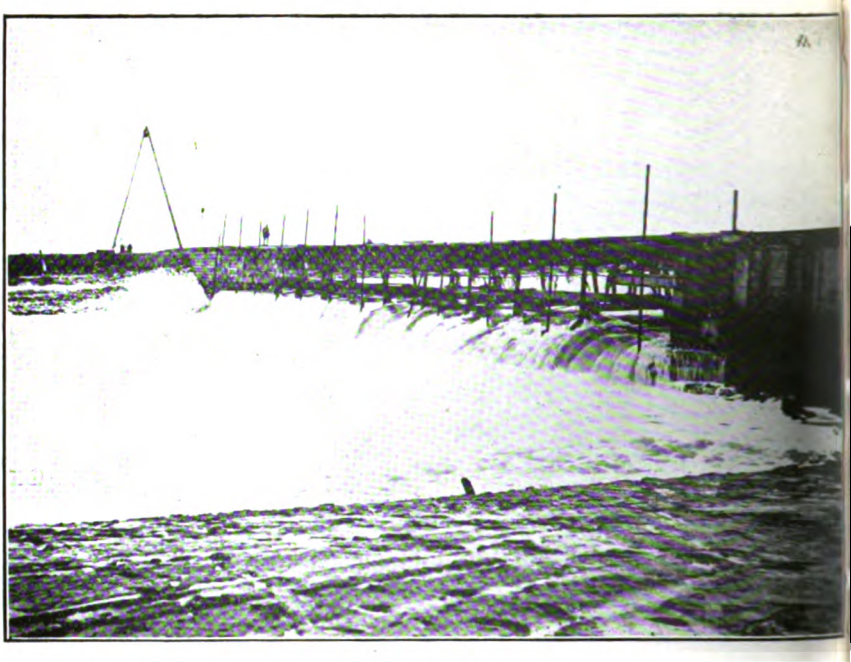

Photo 7.

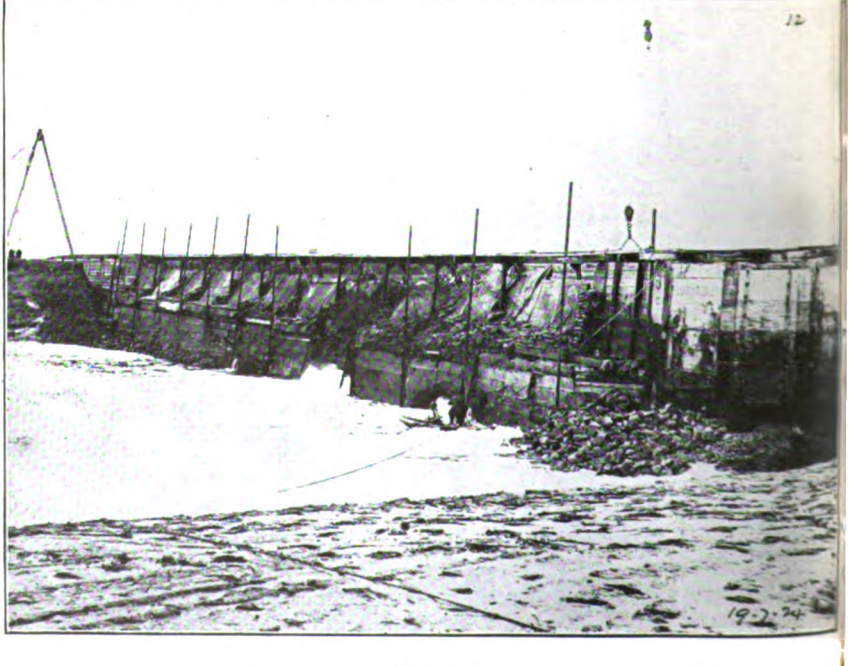

Photo 8.

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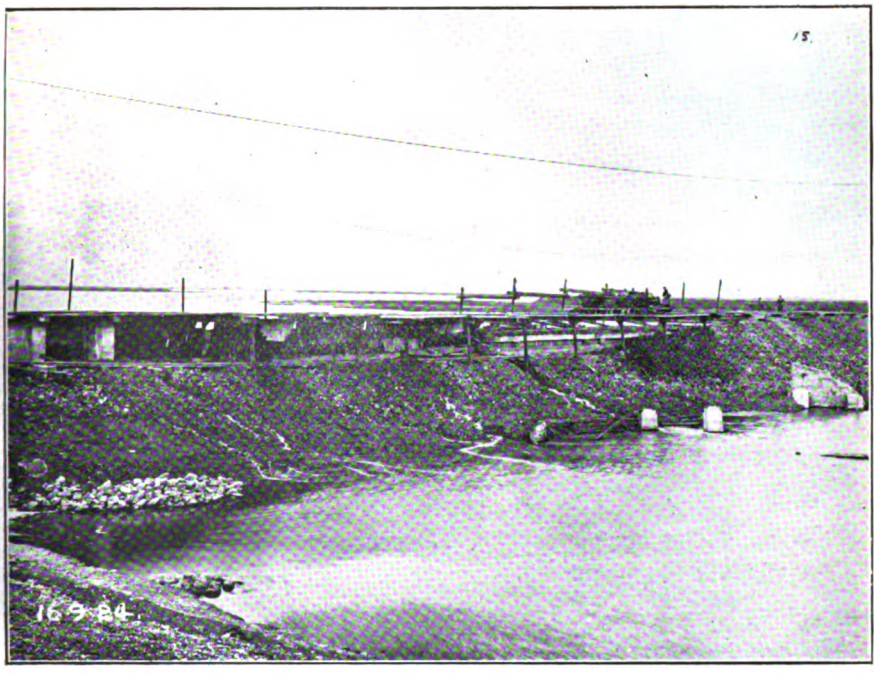

Photo 9.

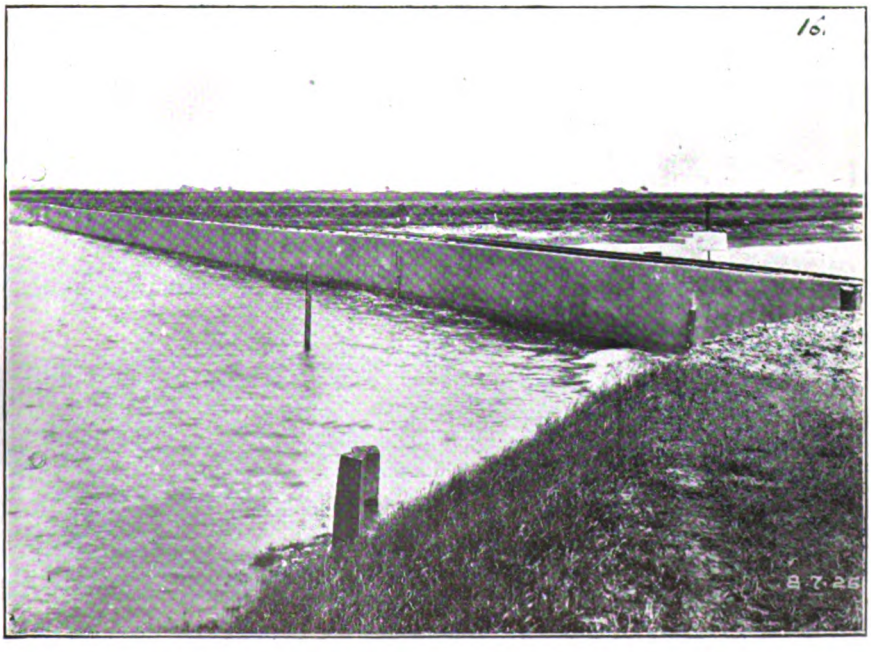

Photo 10.

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Photo 11.
The Flooded Island.

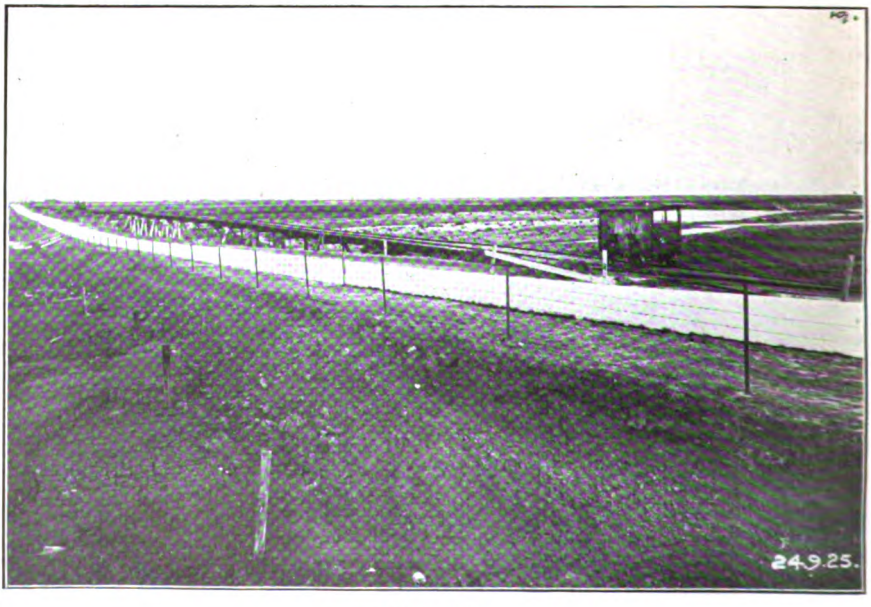

Photo 12.
The Island Reclaimed.

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release than nuts would have been. The flaps acted as the front casing, and the thickness of concrete was regulated by the rebates in the piers already mentioned. To enable the tie-rods to be readily released they were passed through pipes placed between the casings. Condemned boiler tubes proved very useful for this purpose.

To give each pier the benefit of assistance from this additional concrete as soon as possible, the panels between them were filled in alternately instead of consecutively from the Havengore end. Two mixers were used simultaneously, and extra speed was ensured by a separate engine running up boulders to add to the mass. These alternate panels were concreted in before the return of the springs.

The maximum rise of water behind the dam after the flaps were dropped was ten inches, but this all ran out again at low tide. To enable concreting to be started at once in the morning, whatever the state of the tide, the crevices round the particular flaps concerned were stuffed up with strips of old blanket, and the bottom three-feet of the compartment concreted in overnight. Into such crevices as were too wide for blankets, bags filled with clay were rammed.

Concreting the panels proceeded at the rate of three a day, and a point was reached when only five more remained to be filled, *i.e.*, one-and-a-half days' work.

Dam Breached.

At this juncture the elements put in a concentrated attack. During the night a tidal wave swept up the Channel. The wind which had been blowing steadily during the day from the south-west, a safe quarter for this particular work, veered round to the north-east and increased to a velocity of over fifty miles an hour. Heavy snow fell all night in the Thames Valley, and the tide, which had been falling off from maximum springs, suddenly rose three feet higher than its level on the preceding day. Huge holes were torn in the concrete-faced walls of Foulness, those of Canvey Island were breached, and barges were stove in up the Thames.

The dam in its incomplete state did not survive, and about 180-ft. of it was destroyed in the centre, namely, from pier 4 to 21.

From the position of the debris, some of it carried over fifty yards away, it was clear that the unconcreted panels were the first to give way. These pulled over the adjoining piers, which were tied together at the top by the horizontal rails supporting the hinge of the flaps, until a sufficient waterway was provided for the inrushing sea. It was also clear, from the fact that some of the reinforcing frames, of six square inches section, had snapped in two, that the battering of the waves had subjected the dam to

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a far greater dynamic force than the static weight of even a record tide.

The one bright feature of the wreckage was the fact that the front pile line remained intact, and sufficed to prevent scouring of the site from reaching unmanageable dimensions before proper precautions could be taken. Even so, on each side of the pile line scour-holes formed to within four feet of the bottom of the piles. (*Vide* Fig. 13 showing maximum erosion.) Another fact was that the sluice was undamaged.

Reconstruction.

The problem of damming the creek was now more complicated than it had been, both because of the scour and because it was impossible, without undue expense, to replace or remove the back pile-line which had been flattened out *in situ*, and thus obstructed the driving of any more piles. The position was further complicated by masses of debris which were lying athwart the site (Photo 6). These could not be blasted out of the way without great risk of injuring the front pile line, and upon this every hope of reconstruction depended.

It was decided, therefore, to replace the back pile line by a mass of boulders across the breach, upon which to found the new dam; to rely upon the single surviving pile line as a seal against underscour; and to incorporate as much as possible of the debris in the fresh structure. The first step was to protect the exposed ends of the old dam from being undermined, and this was done by depositing stone from cutters manœuvred into position at high tide.

As about two thousand cubic yards of stone was required to fill the various scour holes behind, and up to the level of, the pile line, *i.e.*,—3.5-ft. O.D., some quicker method of dumping had to be devised than handling it on the aerial and in any case the barge containing the winding engine had been returned to the R.A. Also for subsequently running out concrete a high- and low-level railway would be required. The trestles shown in the various photos of reconstruction were, therefore, designed to suit all purposes. The legs and sills were 6-in. x 5-in. R.S.J.'s and the two transoms 12-in. x 6-in. R.S.J.'s, with 3-in. x 3-in. angles as bracing for the lower half. The upper part had, of course, to be left clear to take the construction trains, and could not, therefore, be cross-braced.

Photo 6 gives a good idea of the ten trestles and the position of various portions of the destroyed dam. The sill of some of the trestles can just be seen above the water. The front legs rest on the pile-line, and the back ones upon the wall of stone. (Fig. 13.)

The stone for this wall was run out along the top of the surviving portion of the dam in front-tip trucks, and shot down a 30-ft.

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shoot suspended from the aerial. As soon as enough stone was deposited to form a support for the rear leg of the first trestle, the latter was placed in position by means of the aerial, the line was extended on to it, and stone shot forward as before to form a heap upon which to rest the next trestle. The process was repeated until the line was restored across the creek. The weight of the trestles was distributed on the boulders by a layer of piles laid flat under the back legs, giving an area of ten square feet

It was about six weeks after the destruction of the original dam that the first trestle arrived from the manufacturers, and another five weeks before communication over the top of the dam was re-established. This was at the beginning of April last year, and as the days were now lengthening and "Summer time" imminent, it was possible to look forward to more rapid reconstruction.

Fig. 13 gives a section of the new dam. The intention was to concrete up to + 5.5-ft. O.D., erect piers at 16½-ft. intervals, *i.e.* the same as the trestles; and drop shutters between them as before. The extra weight of concrete in the dam before closing was one of the factors relied upon to prevent a repetition of the previous failure before full weight could be added, and the second was that the water impounded behind the dam would prevent the front face from being subjected to more than a portion of the pressure due to the head of water against it at high tide, until the dam was completed. The impounded water could then be run out through the sluice.

Such was the plan, but the sea had other views.

In the early stages of concreting, it was comparatively easy both to deposit concrete in water and to protect it from the rush of the tide in the way which has already been described. To take full advantage of low tide, four concrete mixers had been installed on Havengore, and in one week as much as 250 tons of concrete were deposited, with 50 tons on each of two successive days.

As, however, the available waterway became reduced, owing to the dam rising, the velocity of the tides increased to such a point that no amount of loading with stone and rails sufficed to prevent the tarpaulins, protecting the newly deposited concrete, from being displaced. The outgoing tide, in particular, became a miniature Niagara (Photo 7), and in addition to removing the fresh concrete, swept away the stone apron which had been placed in front of the dam to prevent the bed of the creek from being still further eroded. (At this stage bays 1, 6-11 were up 5.5-ft., 2 and 3 were 2.2-ft., and 4 and 5 were one course higher at 3.7-ft.)

As a result of this waterfall effect the bed of the creek was scoured right up to the pile line, and the sixth profile rail in the photo has already dropped about 10-ft. from its original level, thus

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measuring the depth of the hole. Clearly no time was to be lost if the inevitable deepening of this action to the bottom of the pile line and the destruction of the dam a second time was to be prevented, and some means of shutting out the sea altogether had to be improvised.

EXCLUSION OF THE SEA.

The trestles were peculiarly adapted for the rapid erection of the necessary barrier, Photo 8 and Fig. 14 showing how this was done. Timber baulks 14-in. x 14-in. were laid horizontally along the middle transoms and strutted back by smaller timbers to the back legs. Against these baulks sleepers or piles were inclined and covered over with tarpaulins, while sandbags were laid at the bottom to keep them from lifting as the tide rose. Outside the front trestle legs 100-lb. rails were laid on the concrete to prevent the possibility of the foot of the sleepers and piles being pushed inwards.

Most of the baulks were suspended over their true position by tackles on the evening before the day fixed for erecting the barrier. It was fortunate that an attempt was not made to do the whole task in the one day, because it took longer than was anticipated, owing to the impossibility of getting more than a certain number of men on to the dam at the same time. As it was, it required seven hours to close the opening, and the flood tide was actually running through when the last piles were being put into position. Four thousand sandbags were used in holding down the tarpaulins and closing the gaps between the sleepers and piles on each side of the trestle legs. The men were knocked off for a rest while the tide rose, so as to be fresh to meet any emergency which might arise at high water.

A high tide was expected as the wind was in the north-west and freshening rapidly. Both continued to rise until nearly an hour after the predicted time of high tide, and the water level was then 11½-ft. above O.D., with wave lap up to 13½-ft. This was higher than parts of the sleeper barrier, and a double row of sandbags had to be laid along the top to keep the sea out. Even then a certain amount splashed over, but without doing any damage, except to the feelings of the constructors, who could only hope that the water would rise no higher.

At last the tide began to fall, but the sea was not done with yet. As the water dropped below the level of that impounded behind the dam, it was seen (Photo 8) that there was a large outflow from back to front. For a short time it looked as if the pile line had been undermined, but as the tide fell still further, the rush of water was seen to be coming over the top of the piles, and it then became evident that two large masses of comparatively

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green concrete in bays 2, 4, and 5, had split off along lines of cleavage caused either by the debris of the old dam or the top of the pile line. This was sufficiently unpleasant, but at least manageable, which would certainly not have been the case if the pile line had been undermined.

The position now was that the barrier, the dam, and the impounded water between could keep the sea out, but that it was not possible to close the " blows " (another smaller one had made its appearance) by tipping earth on the front face, or by any other means, because it would be at once displaced at low tide by the water rushing out. The " blows " could, therefore, only be closed after the impounded water had been allowed to run out, but it was not safe to remove its weight from the back of the dam until corresponding weight had been added in its place, in the form of concrete and earth. At the same time it was inadvisable to allow the sea to rush in and out of the blows a day longer than could be helped, as it was certain to enlarge them in the process.

Several things wanted doing at the same time, namely, making good the scour in front of the pile line, particularly in front of the blows, raising the concrete on the dam to a uniform level, and depositing as much earth on the back face as was possible, in case any higher tides came along.

About 1,500 cubic yards of earth per week were run out to meet the first and last of these requirements, and the best day's concreting produced 84¾ yards.

When about 8,000 yards of earth had been tipped, it was considered safe to run the water out from behind, and the blows through the dam were then almost completely stopped for the time being by tipping more earth in front. It now appeared that the foundation of the dam upon ragstone, underlying the concrete, instead of upon concrete right down to the bed of the creek, proved of the very greatest advantage, for the water rushing in through the blows could distribute itself and lose its velocity in the interstices of the ragstone throughout the length of the dam, if it so desired, instead of forcing an outlet opposite its entry by scouring out the bed of the creek.

With the question of the blows momentarily disposed of, it was possible to continue concreting the dam, and this was done bay by bay, the sleeper barrier being removed and the old concrete being chipped clean of creosote which the sleepers left behind.

When this had been completed there was nothing to prevent the concreting of the dam being continued. The foundations in bays 2, 4, and 5, were restored by driving down a cofferdam of piles round them, excavating the apron to -4-ft. and filling in with concrete, which was strengthened over the pile line by B.R.C. fabric (figure 13). Neap tides were selected for removing

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the barrier in each bay, and replacing by mass concrete. This was necessary because the lowest point of the concrete in front of the barrier was only two feet above Ordnance datum, and the casings would have bulged if the height of concrete put in at a time had exceeded six feet.

Even on neap tides, however, there was no certainty that high water would not exceed 8-ft. O.D., and on one occasion it rose during the night to nearly 10-ft. without, however, doing any damage beyond washing away a considerable amount of earth behind the bay being concreted. (Sandbags were always lined along the top of the concrete up to 9-ft., but in this case the height was insufficient.)

It was unfortunate that at this time "Ferrocrete" cement had not been put upon the market, for its use in the dam would have entirely prevented all the trouble and anxiety caused by the blows, seeing that a few days after placing, it would have had the strength only attained by the ordinary cement used in some weeks. It has since been used on sea-wall work, requiring rapid hardening, with complete success, and is undoubtedly a most valuable addition to an Engineer's resources. It must, however, be used within six weeks of manufacture, after which its quick-hardening properties gradually disappear. Its price, under £3 10s. per ton delivered at Shoeburyness, places it in an entirely different category as a practical proposition to "ciment fondu," which was over £9 a ton at the time in question. (English "ciment fondu" has just been put on the market at £6 1s. 6d. a ton.)

The low level railway over the dam was retained to remove the 14-in. x 14-in. baulks which had supported the barrier, and was then dismantled to make room for further earth backing. Photo 9 shows the barrier in position in the first five bays, (with concrete behind it up to + 8-ft. O.D.); the barrier removed and the baulks being used for casing in the next four bays; while beyond, the low level line has been pulled up and the earth backing is well advanced. Towards the left of the photograph, water will be seen trickling through between the piles. This was encouraged, as it served to saturate and distribute the earth behind the dam and helped it to settle to the angle desired, thereby saving a great amount of shovelling.

Work proceeded according to plan (though somewhat retarded by the withdrawal of twenty men to put through an urgent requisition for the Royal Air Force), until it was noticed that no amount of earth filling on the front entirely prevented a small trickle through the dam at the Havengore end near the sluice. It became evident that this water penetrated at a point thirty feet from the dam (where a scour hole caused by the steam barge used in the early days of pile-driving had been filled in partially with ballast

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and stone) and, passing up through the stone pitching of the sluice outfall, then found its way through one of the piles holed to take a reinforcing frame of the old dam. The only remedy for this was to extend the front apron right over the sluice, in the hope that the weight of water would force the earth into the interstices of the stone and so seal the leak.

This was accordingly done, with the result that no water whatever now gets through the dam, but the water level in the creek behind it has risen over three feet to Ordnance datum. This is of no real consequence, as the catchment area draining into the creek is small, being only a portion of Havengore Island and New England.

If upon re-opening a channel from the sluice, which is now closed, it is found that water starts once more to penetrate the dam, the sluice can be covered over again, and the drainage from Havengore diverted to another outlet into Havengore Creek. Similarly, if water rises behind the dam, as a result of rainfall on New England alone, to 6-ft. above O.D., the level of the road just completed over the Island, it can be released by making a new outfall into Shelford Creek. Such a rise, however, is most improbable, in view of the area of the creek and that of the land draining into it.

Photo 10 shows the completed dam as reconstructed. On reconstruction alone 2,500 cu. yards of ragstone boulders, 2,100 cu. yards of concrete, and 19,000 cu. yards of earth were used, the net cost of this work being approximately £7,000. Concrete was 1 in 7½, except where laid in water or places where the tide was exceptionally strong, when it was strengthened to 1 in 5. This point was elaborated in the previous article.

As the result of experience gained from the vicissitudes of this dam, it would appear that the best method of building any similar dam in future, would be by a combination of the two systems described above. It is certain that the bearing power of the piles should be utilised to the full, as in the reconstructed dam, for not even the minutest sinkage has taken place in it, whereas the other two dams, the construction of which was described in these pages two years ago, have sunk, with a maximum in "C" dam of six inches. It is also certain that the first method of shutting out the tide at a time of one's own choosing is better than the second, at the bidding of the sea.

It is clear, too, that all calculations must be based, not upon the finished work, but upon the conditions prevailing immediately the flaps are closed; and to ensure the necessary strength at that time under the most unexpected circumstances, the base of the dam must be wider than it was made in the first case, and heavier. The latter can be ensured by raising its height before closing the flaps, and the weight of the impounded water is also a valuable

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factor. The height to which concreting can be carried out depend upon the rate at which the bed of the creek is being scoured b the outfall over the dam. It seems that about half tide on th springs is the point beyond which it is unwise to go. In the presen case this would be represented by + 3-ft. O.D., instead of th +5.5-ft. attempted.

Smaller Dams.

So far the construction of dams ranging between 200 and 400-ft long has been considered, and the reasons (in the former article which led to the adoption of concrete.

In smaller dams, such as can be built on one fortnightly tide cycle, it is possible to make use of earth without keeping the sea out by a preliminary wall of piles.

The northern end of New England Island is separated from the remainder by a horseshoe-shaped sea-wall, " F " on the plan, and was flooded independently through a breach in the main sea-wall at " A." This breach divided into three main channels, of which the largest was 65-ft. wide, and in depth 2-ft. below O.D. The other two were 40 and 30-ft. respectively. Calculation showed that the first would require about 1,600 cubic yards of earth, and it was clear that if this one could be stopped by tipping earth into it, there would be no difficulty about the remainder.

The method of closing this portion of the island was as follows: The 2-ft. gauge railway running out on to " B " dam was extended across the island and taken across the three gaps on 14-in. x 14-in. timbers, with an intermediate trestle in the case of the largest. The line was kept as high as possible over the gaps with the object of giving the earth the maximum drop when tipped so as the better to consolidate it, and to reduce the dressing of it afterwards as much as possible.

Six borrowpits were laid out on Havengore (from which earth was also taken for " B " dam) with a siding into each. Although these were half-a-mile away from the breach, the earth therefrom was much more suitable than that from the island, and they were not subject to being flooded at high tide, with the attendant difficulty of drainage.

When all was in readiness, earth was run out in tip wagons of one cubic yard capacity, and dumped into the largest gap as rapidly as possible. Three 20 h.p. " Simplex " petrol tractors were employed on this service, each being responsible for two trains of four wagons. Twelve diggers were detailed to each pair of trains, and filled one while the other was away being emptied.

The chief difficulty encountered was the frequency of derailments owing to the line being laid over mud, semi-liquid to a depth of two feet in the worst places. A special re-railing gang had to be

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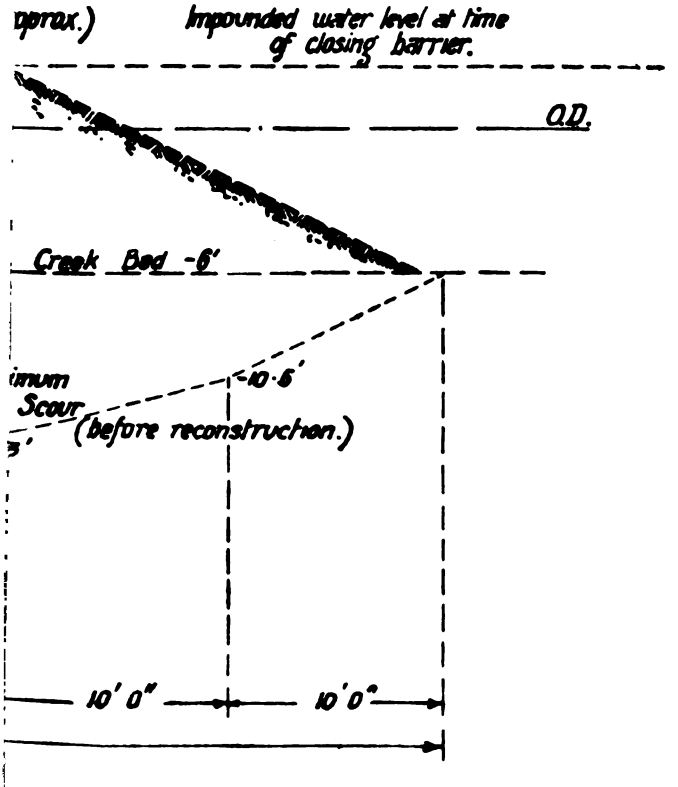
FIG. 18.



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detailed until the weak places had been dealt with by packing up on good soil brought from Havengore. It was particularly hard to keep the rails level round curves, which could not altogether be eliminated. At the same time, since the line would only be required for a fortnight or three weeks, it was not worth while doing more than the minimum levelling and packing.

The original idea was to spread the first day's earth, about 200 cu. yards, to a depth of three feet, so as to restrict the waterway only a little, and to cover up with sailcloths till the next day. The earth was so stiff, however, that spreading it required as much labour as the original excavation. This task was accordingly left to the tide to perform when it burst over the top of the day's work. This it did very satisfactorily, and the net gain on the first day was the impounding of two feet of water behind the dam.

On the second day the dam was raised almost high enough, but not quite, to top the tide. The irruption was not so violent as on the former occasion. A further rise of the impounded water showed that the dam could be made good on the third day, and this was done. The next few days were devoted to getting as much earth into place as possible, both to raise and widen the dam, but also to make good the loss of height as the soil subsided to its natural angle of repose. When the springs came round again the dam was too strong for them to destroy.

Water trickled through the dam for over a week, but these weepholes gradually sealed themselves as the earth became consolidated. The impounded water started at a level of about two feet below the general level of the island, but this was reduced as it scoured its way out through the other two outlets. (It is an advantage to impound as much water as possible during operations of this kind in order to minimise the amount which has to pass to and fro. It can always be evacuated when the dams are complete; in this case by making a passage for it through the sea-wall behind "B" dam, whence it can escape through the sluice.)

The scour of the two subsidiary channels, alluded to above, was checked by stone pitching, and the dams were put in hand on the first day of the next neap tides. The larger one was successfully dammed in one day, but was nearly topped by the tide next day, owing to subsidence during the night. The smaller one, which had been dammed at the same time, had been left slightly lower to act as a safety valve, and this was swept out by the tide, which was 18-in. higher than normal for its position in the fortnightly tide-cycle. It was made good next day and men concentrated to build the intermediate portions of wall which were required to complete the new defences round the original breach to a height of 4½-ft. above the island as a first step. This raised

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it a foot above any except a "freak" tide, leaving it to be raised to the full height of 16-ft. above O.D. (6-in. allowed for settlement) as soon as possible.

The soil at this end of Havengore was much harder to excavate than in the vicinity of "C" dam, and each man could only dig 8 yards a day as against over 13 yards at the latter. Even so, on the shorter winter day they were doing over a yard per man per hour. Three men to a truck was the best number to balance the trips. The maximum output per man was achieved when three engines were hauling for two gangs of twelve men, the third gang adding little more than 50 per cent. of a gang's output owing to traffic delays.

For sea walling proper the best arrangement is to have three men digging and wheeling to one "builder." Any larger number of men working at one point get in each other's way and send up the cost per yard proportionately. On this reclamation work, the cost averaged 7s. 6d. a yard, excluding the three deep breaches above mentioned, the closing of which cost £1,400. As against the original scheme of building a fourth dam at "A," the scheme adopted showed a saving of at least £5,000.

It is not generally possible to select the time of year for closing creeks or breaches in seawalls, but, if it should be, the bird-nesting season is the best. What are called "bird-tides" occur then, during which, by a wise dispensation of Nature, spring tides are much lower than usual. This allows birds of a nautical turn of mind to build their nests on the saltings without fear of being flooded out, and quite near one section of seawall which was being repaired, a wild duck hatched out her brood, unmolested by man or sea, at a level no higher than 10-ft. above Ordnance Datum.

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NOTES BY A CHIEF ENGINEER DURING THE GREAT WAR OF 1914-1918—(*continued*).

By BRIGADIER-GENERAL W. BAKER BROWN, C.B.

ON arrival in London in March, 1915, I reported at the War Office and saw Major-General G. K. Scott-Moncrieff, the Director of Fortifications and Works. On 20th March I received notification that I had been appointed Chief Engineer Eastern Command and should report for duty on the following Monday.

In order to shorten these notes and to present an outline of the work done and the methods we adopted, I propose to make, first of all, a summary of the various changes of organisation of the Eastern Command itself, and then to deal with the Engineer work under various headings, such as organisation, defences, hutting, etc.

THE EASTERN COMMAND.

On the outbreak of War the Eastern Command comprised the twelve counties of Norfolk, Suffolk, Essex, Cambridge, Huntingdon, Northampton, Bedford, Hertford, Middlesex, Surrey, Kent and Sussex, except the areas included in the London District and part of West Surrey, which came under Aldershot. To this was added during the War the greater part of the county of Buckingham. The Command included the defended ports of Harwich, Chatham, Dover and Newhaven, and the peace stations of the 4th Division of the Field Army with Headquarters at Woolwich. Two Territorial Divisions—the East Anglian and Home Counties—also had their Headquarters in the Command.

The Headquarters office of the Command was at the Horse Guards, and the Administrative work was on the usual peace footing with a Major-General of Administration to whom the heads of Services and Departments reported on administrative questions, and through whom all funds were allotted. The G.O.C. in March, 1915, was Lt.-Gen. C. L. Woollcombe, C.B., and the General of Administration was Major-General J. Adye, C.B. The sub-division of work followed the ordinary peace routine, but all the senior appointments except that of the C.G.S., the Chief Engineer and the Deputy Director Medical Service were filled by retired officers.

The position of the London District was peculiar, as not only did the main portion of the District constitute an island in the middle of our Command, but it also administered detached areas which were occupied by the Brigade of Guards at Caterham, Windsor

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and Purfleet. On the other hand, London being the only possible centre from which the Eastern Command could be worked, it followed that the Headquarters of the Command had to be situated in the London District, with the result that all services connected with our own office, such as lighting and repairs, had to be carried out by the London District staff.

In addition to the troops in the Eastern Command, which numbered nearly 300,000 men, and may be considered as an expansion of the peace garrison of about 45,000 of all ranks, there was living in our area a separately organised field Army called the "Central Force." This was composed of about nine Divisions of the Territorial Army with two Cavalry Divisions of Yeomanry and various cyclist units. The Central Force was organised on a war footing similar to that of the Expeditionary Force, and was commanded by General Sir Ian Hamilton, with a staff organised in the three sections of G.A.Q.

The Headquarters of the Central Force was in the Horse Guards alongside those of the Eastern Command and the London District. The Central Force was divided into three Armies with headquarters at Cambridge, Dunmow (Essex) and Tunbridge Wells. No provision was made for an Engineer-in-Chief at the Headquarters of the Force, but it was soon evident that some Engineer organisation was essential, and Major-General R. M. Ruck, C.B., was appointed Chief Engineer of the Force, with a suitable staff and with an office in the Institution of Civil Engineers. A Chief Engineer was also appointed to each Army. The infantry of the force was distributed on a line roughly north and south through London, while the cavalry and cyclists formed a line of outposts ten to twenty miles from the coast, the idea being that if a landing took place, the outpost line would retire on certain selected positions, where the infantry could be concentrated as required. This force, for purposes of administration, at first acted as an independent force in a friendly country, and made its own arrangements for supplies, quartering, hutting, etc., quite apart from the Command in which it was placed, going direct to the War Office on all financial questions.

London Defences.

To add to the complications of areas there was a separate organisation at work digging the defences of London. This organisation was controlled by the C.E. of the Central Force, Major-General Ruck, who was appointed G.O.C. London defences. The organisation was controlled by retired R.E. Officers and the work was carried out by local organisations. The whole of these defences was in the area administered by the Eastern Command.

To revert to the Eastern Command, on the outbreak of war the Chief Engineer was Brig.-General C. F. Anderson, C.B., and the

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staff officer appointed on mobilization was Major E. H. Hills, C.M.G., R.E. Hills was in the Reserve of Officers, and on the outbreak of war was in Russia in connection with the observation of an eclipse of the sun. He returned via Sweden and Norway and took up duty about 15th August, to find that Anderson, who was a great authority on "ciphers," was away a great deal in consultation with the General Staff at the War Office. The personal supervision of the engineer services of the Command thus fell to Hills, and when Anderson was withdrawn altogether for duty at the War Office in September, 1914, Hills was appointed temporarily to act as Chief Engineer with the rank of Colonel. In November, 1914, Col. E. Roper, who had been withdrawn from South Africa, took up the duties of Chief Engineer, until I relieved him in March, 1915.

The principal work carried out up to this date was the hutting for the troops during the winter of 1914-15. This I will deal with a little more fully later on in these notes. Meanwhile the arrangement under which the Central Force carried out their own administration had been found very difficult to work, and proposals were being discussed between the staffs of the Central Force and the Eastern Command, under which the administrative arrangements of the Central Force would be handed over to the Eastern Command, leaving the staff of the Central Force to deal with defensive arrangements, and the ordering of movements necessary for defensive reasons.

In connection with this reorganisation the Chief Engineers of the Central Force and Eastern Command had prepared detailed proposals for the transfer of Engineer Services, and for the formation of new C.R.E.'s Districts to deal with the extra work. This scheme was only in the rough, and my first job was to put it into shape, rearrange Districts, appoint new Division Officers, and so on. With the amalgamation of the Central Force the ration strength of the Eastern Command in the middle of 1915 exceeded 550,000 men, and I found there were in the Command about 85 officers of the rank of Brig.-General and upwards.

When we began work under the new organisation it was found, as might have been expected, that handing over the duties of Administration to the Eastern Command involved practically direct communication between the Eastern Command heads of services and the heads of the fighting organisations, such as Divisions or Armies. In fact the Q staff of the Central Force had become a fifth wheel to the coach.

On the other hand, in the case of general staff work there was an obvious inconvenience in questions of defence in the Fortress areas being dealt with by the general staff of the Eastern Command, while

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similar questions affecting the field areas came to the general staff of the Central Force.

For these and similar reasons General Sir Leslie Rundle, who had succeeded Sir Ian Hamilton in the command of the Central Force, put forward a proposal to amalgamate his command with that of the Eastern Command, with a concentration and reduction of staff. This was approved. On working out the details of the amalgamation it was considered necessary to retain the Chief Engineer of the Central Force to deal with all questions of field defences, including the field defences of London. All other branches of the staff were amalgamated. The peace form of staff organisation was adopted and the Major-General of Administration was retained. The head of the Q branch of the Central Force staff was made Assistant to the M.G.A., with the special duty of supervising the work of the special inspection staff for Q.M.G. services, who visited barracks, hutments and camps, and reported on the efficiency of the accommodation, rations, cooking, etc. The Assistant to the M.G.A. did not act as an intermediary between the M.G.A. and the heads of services, and the latter reported direct to the M.G.A. when necessary. In practice we all tried to relieve the M.G.A. of as much detail as possible, and the Chief Engineer, as well as the other heads of services, had full authority to act for the M.G.A. in an emergency, provided we kept him informed on all important questions.

In October, 1915, Major-General Sir J. Adye left the command to take up the appointment as I.G.C. to the forces in the East, and later in Egypt, and Major-General R. M. Ruck was appointed M.G.A. in his place, being a little later relieved by Col. F. H. Horniblow as C.E. Central Force. This arrangement of duties continued during 1915, and under this régime a large amount of useful work was carried out; among others the anti-aircraft defences were entirely remodelled, hired houses were organised into groups to suit the organisation into Divisions and Brigades, hutted camps were completed and improved, a large programme of summer camps was carried out, roads attended to, hospitals enlarged and improved, and all the financial, contract and other detail involved was put on a thoroughly business-like footing.

Among other changes of importance, the Headquarters of the Canadians in England was, early in 1915, shifted to Shorncliffe, and they rapidly accumulated a strength of 30,000 in that neighbourhood. On the whole we may fairly claim that by the winter of 1915-16 we had tackled all our problems and had placed the accommodation for troops on a thoroughly good and sanitary basis.

Towards the end of 1915 a change took place in the appointment of a G.O.C. Home Forces which affected our organisation and work very considerably. The ostensible reason for such an appointment was the desire of the General Staff at the War Office to be relieved

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of the work of corresponding with individual Commands at home, so that they might have more time to attend to the numerous campaigns which were in hand overseas, though this result was not obtained in practice. It was also desired to form a special staff which might have more time to superintend the details of training of the very large number of troops at home, and on this point the new organisation was quite successful. On the other hand it did not appear that the other branches of the War Office were anxious to delegate any part of their work to a new authority, as it was fully realised that though these Islands had their own problems of Home Defence against attack by sea or air, they were also the principal base from which all our overseas campaigns drew supplies of men and material. And in connection with this there was a very marked tendency in both the Civil and Military branches to concentrate control at Headquarters. It was therefore decided that the G.O.C. Home Forces would have no financial responsibility, and that this would continue to be exercised by the Major-Generals of Administration of the various Commands under direct instructions from the War Office. The staff of the G.O.C. Home Forces was formed on a war basis with G, A, and Q branches, but had at first no Engineer-in-Chief, or, indeed, any representatives of technical services. The Q branch of this Force was, therefore, as regards Engineer services, only an office to communicate the wishes of the G.O.C. Home Forces to the various commands, and the latter had the responsibility of approaching the War Office, getting financial approval of any proposals and collecting the necessary material and labour to carry them out. As there was from this time onward considerable shortage under both these heads, the work involved in getting proposals worked out and approved was very considerable. By this time also the London District had overgrown its bounds, and was frequently calling on us to provide camps, hutments and schools in our area. Among other details the divisional hutment at Seaford was handed over as a convalescent centre for the Brigade of Guards, but the Eastern Command remained responsible for administrative services. At the same time we often got orders direct from the War Office to provide special accommodation, such as venereal hospitals, storage for one-and-a-half million rifles at Weedon, or the large mechanical transport depot at Kempton Park, all of which made further calls on our staff and on our limited supplies of material and labour. But somehow or other the work was done.

The advent of the G.O.C. Home Forces also produced other changes, as he reverted to the earlier organisation under which the G.O.C.'s of the Field Armies reported direct to the G.O.C. Home Forces, and not through the G.O.C. of the Command in which they were stationed. At the same time the number of the Armies in our Command was reduced from three to two, with headquarters in

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Norfolk and Essex. The appointment of Chief Engineer, Central Force, was abolished, but each Army had a Chief Engineer who was responsible for the training of the R.E. Field units and the construction of the Field Defences. Up to this time the responsibility for the supply of stores and tools for the construction of these defences had rested with the Chief Engineer of the Central Force, who had a special officer for stores in his office. With the abolition of this C.E. the responsibility for the supply of these tools and materials was transferred to the Eastern Command, and arrangements were made for their supply through the local C.R.E.'s.

The Administrative services of the Field Force remained under the Eastern Command, but were carried on under rather more difficult conditions, as the General officers commanding Armies and Divisions not having any personal responsibility were apt to demand the immediate execution of services, which we were either unable to carry out or which required considerable time for their execution. These difficulties were gradually met by a series of personal visits and local discussion with officers concerned.

Another change made by the G.O.C. Home Forces was an alteration of the tactical scheme for the distribution of the troops. I have stated above that the original scheme prepared by the War Office and followed by Sir Ian Hamilton was to watch the coast with Cavalry and Cyclists, while the Infantry Divisions were kept well back ready for concentration in certain prepared positions. Under Sir Leslie Rundle the infantry was pushed forward, so as to be able to support the outpost line more quickly, and the accommodation provided during 1915 was based on this scheme. Now Sir John French ordered that the line of high water mark along the coast should be adopted as the main line of defence, thus abolishing the line of outposts. The Cavalry was concentrated on the north flank in Norfolk and the Cyclists distributed among the armies. These changes gave a great deal of work both for summer camps and winter quartering. In the summer, instead of re-occupying the camps prepared in 1915, many of which had been kept standing, a large number of new camps had to be made in new positions involving accommodation for 200,000 men. This was successfully completed. But the winter accommodation was not so easy, as it involved a very considerable hutting scheme all along the coast. By this time the supply of timber was getting very short and the War Office was unable and unwilling to provide a big programme of hutting to meet a change in the distribution of the troops which was not vitally necessary. But after much discussion, I obtained 1,000 small wooden huts of a new type just evolved by Col. Armstrong, capable of accommodating about 15,000 troops in all, and by using these to supplement the accommodation in villages we managed to

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establish a fairly strong outpost line in the neighbourhood of high water mark.

In order to provide office accommodation for the G.O.C. Home Forces it was decided to remove the Headquarters of the Eastern Command from the Horse Guards. Fortunately we were able to obtain the use of a new seven-storied office building at 50, Pall Mall, into which we were able to put the whole of the Command staff. Further, as the interior sub-division into rooms was not completed, we were able to arrange this to suit the various requirements. The whole of the fifth floor was allotted to the Engineers, and for the first time we had the whole of our staff within easy call. The number of the C.E. staff at this time was 13 officers and 19 other ranks, including five girl typists. The saving of labour compared with the scattered accommodation at the Horse Guards was very marked, while the proximity to the M.G.A. and the other heads of services made all inter-departmental discussion much easier.

The change in the organisation of the Field Force involved the withdrawal of Sir L. Rundle from the Command, and in March, 1916, he was replaced by Lt.-Gen. Sir J. Wolfe-Murray, and in June, 1916, Major-General R. M. Ruck was replaced as M.G.Admn. by Major-General Sir F. Robb, K.C.B.

In addition to the work for the field forces and for the various organisations of the Eastern and London Commands, there was during 1916 a considerable increase in work for the Flying Corps and in connection with the anti-aircraft defences. The hospitals also required almost continual improvement and expansion.

In October, 1916, the War Office decided to bring over to England all the recruits under training in Canada, so that they could avoid the winter in that country. The first we heard of it was an order to evacuate the hutted camps at Crowborough and neighbourhood and to arrange, with these and other accommodation in Sussex, to accommodate 30,000 men, to be increased later by an equal number. The order was accompanied by an intimation that the first 6,000 men had already left Canada and were on the high seas, and might be expected in six days. At the time the only organised area in the Command which would take the training brigade from Crowborough, was at St. Albans, which had been vacated a few months earlier by a Division of Territorials despatched to Ireland in April, 1916. For the remainder I pointed out to the M.G.Admn. that the only important town in the area which was not already occupied was the town of Hastings with St. Leonards, and it was decided to concentrate on this area. The President of the Quartering Area and my nearest C.R.E. from Ashford moved into the town to superintend operations; five valuers were collected from neighbouring areas, and all the empty houses and important public buildings were taken over, organised in suitable groups, each with central dining and

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cooking, recreation rooms, baths and accessories. The War Office arranged for the supply of cooking stoves from the manufacturers in Scotland and for their despatch south in a special train. As a result, on the arrival of the first contingent arrangements were sufficiently advanced to enable them to be received in comparative comfort.

This was the last job of the kind with which I was personally connected in the Eastern Command, as in November, 1916, at my own request, I was ordered to France to take up an appointment under the Director of Works.

Organisation of C.E.'s Office.

On the outbreak of war the staff of the C.E. consisted of one Staff Officer R.E., with a Superintending Inspector of Works, one Lands Officer, and an Inspector of R.E. Machinery, attached for special service, and the usual subordinate staff of clerks, draughtsmen and mechanists.

Soon after the outbreak of war, some of the senior Engineer clerks were given commissions and appointed assistants to the S.O.R.E., and the senior clerk in the Eastern Command was commissioned at this time. I found, however, when I arrived in the Command that this officer, Lieut. and Qr.-Mr. R. T. Gough, R.E., was still acting as Chief Clerk, opening all letters and distributing to branches of the office, while the S.O.R.E. was signing practically all letters which left the office, of whatever their importance. My first effort was, therefore, directed to a rearrangement of duties, and after some discussion we settled down to a routine under which the Staff Officer, in addition to understudying the C.E., dealt with all papers connected with quartering and general works services, while the Assistant Staff Officer took charge of all papers connected with the R.E. personnel and civilian subordinates, and also engineer stores, rifle ranges and telephones. The personnel by this time had increased very considerably, and was to increase much more later. Officers were posted to the Command by the War Office, but were posted to Stations by the Command. Subordinates were selected by the Command, usually on the recommendation of C.R.E.'s and Division Officers, but all appointments were finally approved by the C.E., acting for the Major-General of Administration, and a monthly report had to be made to the War Office of all such appointments. Under ordinary peace procedure such appointments require W.O. approval in each case, and the delegation of authority to Commands was a most valuable concession to War conditions. As the total of our staff reached about 200 officers and 1,000 subordinates before the end of 1916, it will be seen that this item involved considerable correspondence.

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At the same time, with the approval of the M.G.A., I gave the S.I.W. and Chief Lands Officers authority to correspond direct with C.R.E.'s and their own subordinates in the Command on questions of detail, an arrangement which at once relieved the S.O.R.E. of much routine labour. This was the more necessary as the various officers of the C.E.'s staff were scattered in various parts of the Horse Guards building, so that communication between the various rooms of the office was slow and laborious.

Contracts. The superintending Inspector of Works was Col. H. W. Elton, whom I had known for many years, and who had served for some time in the Eastern Command. He had on the outbreak of war arranged direct contracts for the construction of four large divisional hutments in the Command, and after a few months in France had returned and rendered invaluable service in closing up these contracts and in organising the contract branch of the office.

The four big contracts were for the new Divisional hutted camps at Halton Park, Seaford, Shoreham and Sandling, and for these a direct contract was placed with Messrs. Robert McAlpine & Sons on a general specification prepared by Col. Elton. This involved the discussion of a good many extras due to irregularity of site, but the whole of these were settled by Col. Elton with one exception, and the final bill as agreed by the Command was a little over £956,000. The exception was a general claim by the Contractors on a clause in the specification that the sites should be assumed to be level, any departure being paid for in extras. In addition to the extras for foundations which were allowed in our final bill, the contractors made a general claim for an extra for haulage and for getting material on to the sites, amounting to about £90,000. This I did not feel able to accept, as, though the sites were not named in the original contract, I thought the contractors should have anticipated ordinary conditions of country. This question remained under discussion till 1919, when it was settled at the War Office by the payment to the Contractors of about three-quarters of their claim.

Under ordinary peace procedure the powers of the M.G. Admn. of Commands at Home in connection with Engineer Contracts for new services were limited to a maxiumm of £100, every contract above this amount requiring War Office acceptance. The powers of a C.R.E. were limited to £50. On the outbreak of war the limit of powers of a M.G.A. was raised to £2,000. Towards the middle of 1915 this was reviewed and reduced to £200, the argument being that the supply of material was limited, and that it was therefore necessary to control expenditure, and that before an expenditure exceeding £200 was actually incurred there would be ample time to obtain W.O. approval. It was, however, clearly understood that in case of real emergency the

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M.G.A. could order work to be commenced, reporting at once to the War Office. This arrangement worked quite satisfactorily and no case occurred of any delay in the execution of essential engineer work. And on the other hand, when we did order services of an urgent nature we always received the fullest support from the D.F.W. and the War Office.

In connection with the question of contracts, I instructed C.R.E.'s to make the fullest use of their peace powers of entering into small contracts with local firms, and further, gave them authority to delegate to D.O's the power of making a small contract under £25 with a single firm. Under this arrangement, when a service such as latrines for a small camp for a detachment was required in a hurry, the D.O. could make a short lump sum contract with a local builder, the necessary writing taking only a sheet of foolscap, and all necessity for elaborate forms and measurements was avoided. All contracts over £50 arranged by C.R.E's came to the C.E's office for review and all contracts over £100 had to be passed on to the Contract branch of the War Office. Fortunately the War Office Contract branch had obtained the assistance of Mr. J. E. Drower, a well-known Civil Surveyor, with whom we established the most friendly relations.

The number of contracts passed to the War Office for review during the first 12 months of my tenure exceeded 3,000 and sometimes 20 or 30 were dealt with in a day. To deal with this mass of work the Superintending Inspector of Works had a staff of one assistant (with the rank of Lieutenant) three experienced, and, I may add, elderly clerks, and one girl typist.

Lands. Under the peace routine before the war the control of all lands and property in a Command was vested in the Chief Engineer, who had a "lands" office in charge of a senior draughtsman, where all plans and documents were kept, this office being under the direct supervision of the S.O.R.E. There was also in each of the large commands at home a Lands Officer, who was a qualified civilian, who acted as an adviser to the Chief Engineer, prepared all technical documents connected with land, but did not perform executive duties. The Lands Officer of the Eastern Command—Major Thompson—also assisted the London District.

In the War Office the control of "Lands" questions had been withdrawn from the D.F.W. and put under a civilian controller.

With the occupation of new areas under war conditions the work connected with land increased enormously, especially in connection with the occupation of land for field defences constructed round our defended ports. When I joined I found the staff of the Lands Officer had been increased by six temporary officers, of whom three were in the London office and three were working outside London.

The Chief Engineer of the Central Force had a staff of six temporary

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Lands Officers, who looked for technical guidance to the permanent Lands Officer of our Command.

To deal with claims quickly in the War Office a special commission had been appointed, known as "Duke's Commission," from the name of the President, which did most excellent work in handling claims quickly and economically, and gradually laid down a set of precedents and decisions which were most valuable as a guide to local officers. The Lands Officers of the Command attended before this Commission to explain details of claims under consideration.

On the transfer to the Command of the responsibility for the provision of accommodation for the Central Force, I suggested a reorganisation of the Lands organisation, and the six Lands Officers of the Central Force were transferred to my control. Up to this time the Lands Officers had no executive powers, and all the correspondence was conducted in the C.E's "Lands Office," and all letters and minutes were signed by the S.O.R.E. One of my earliest recollections in the Command is about 6 o'clock one evening seeing the Chief Clerk of the Lands Office and his assistant enter the room of the S.O.R.E., each staggering under a pile, several feet high, of "lands" papers, all of which had to be dealt with by the unhappy S.O.R.E. before he left the office. The number of papers dealt with daily often exceeded 150. Only an officer of the ability and remarkable mental powers of Colonel Hills could have dealt with this mass of correspondence without a breakdown.

To remedy this I gave the Chief Lands Officer the authority already referred to to sign letters to his own subordinates in the Command on technical details, and obtained the approval of the M.G.A. to his signing letters to the War Office on minor claims, under £100, which were covered by previous decisions of Duke's Commission, and were of a simple character. All claims over £100, or which involved a new principle, were submitted by the Chief Lands Officer personally to the S.O.R.E., who exercised his discretion as to whether he would deal with the paper himself or reserve it for the consideration of the C.E. and M.G.A. The number which reached the M.G.A. seldom exceeded 6 or 7 daily. By this arrangement the mass of papers was quickly and effectively handled. The Lands Branch finally employed 40 officers and a larger number of subordinates.

Technical Officers. In addition to the four officers described above who formed the staff of the C.E., there was a group of technical officers with special duties.

Electrical. Before the war no provision was made in the peace organisation outside the War Office for any technical control of Electrical services, except that the officers employed in connection with Defence Lights did frequently prepare schemes for barrack and other lighting. For our big hutted camps it was early decided that electric light should be installed, and at first all schemes for this were pre-

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pared at the War Office. I found, however, that those of the Eastern Command and London District were being prepared by a civilian Electrical Engineer, Mr. Wright, and I suggested that if this gentleman could be transferred to the Command we could relieve the War Office of some detail, while Mr. Wright, in addition to new schemes, could deal with the many questions of maintenance and repair which were increasing in number. This was approved, and before the end of 1916 Mr. Wright had prepared and superintended the execution of over 80 schemes for power stations and electrical distribution in our hutted camps, all of which were working efficiently.

Mechanical. The general supervision of machinery in the Command was carried out in 1914 by an Inspector R.E. Machinery with the position of Qr.-Mr. R.E., assisted by mechanists distributed throughout the Command, and this work was continued with an enlarged staff. There was considerable use of small machines, such as pumps, for various services in camps and hutments.

Telephones. The work connected with the administrative telephone system in England is carried out by the Post Office, and while the Central Force was in existence all additions or alterations to telephones were arranged by the Chief Signalling Officer of that force, who was Col. Hippisley (late R.E.). On the amalgamation of the Central Force with the Eastern Command, this appointment was abolished, but a junior officer from the Post Office was appointed to the staff of the C.E., who acted as an intermediary to arrange with the Post Office for the carrying out of any work required. The increase in the use of telephones was very great both in the H.Qr. and throughout the Command, and all our requirements were very promptly met by the Post Office authorities.

Sanitation and Water Supply. In times of peace there are, in the Department of the Government which approves local schemes of sanitation, water supply, etc., a body of highly-qualified technical inspectors, who investigate local schemes and report on them to the Minister concerned—now the Minister of Health. As the work of these gentlemen decreased on the outbreak of war, it was suggested early in 1915 that they might be usefully employed in military engineering work connected with hutting, etc. Eight of them were allotted to the Eastern Command and were detailed as Division Officers in some of the larger hutment centres. After a few weeks a suggestion was made by the War Office that these officers, from the nature of their peace duties, were admirably qualified to assist Commands in dealing with the problems of water supply and sanitation which arose in connection with the numerous hutments and camps. Five of these Officers were then withdrawn for this duty, and posted to the various Home Commands. The arrangement proved most successful.

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The officer posted to the Eastern Command was Lt. E. Hetherington. He was employed in advising C.R.E's and D.O's on all questions of water supply and sanitation, and he was especially useful where questions arose connected with the use or extension of local sewage and water services. He also established a useful *liaison* with the sanitary expert in the office of the D.D.M.S. of the Command, and frequently made joint inspections with this officer. He did most of his work by personal visits and interviews with local officers.

Chief Engineer. It may be observed that in the above distribution of duties no specific work was assigned to the Chief Engineer, and this almost necessarily follows in a large Command, where the Chief Engineer must act as the final reference on all important questions, and must therefore be ready to meet any members of his staff who want to bring questions to his notice. I found also one of his most useful spheres of work was in visiting out-stations and getting in personal touch with the C.R.E's and other officers.

In visiting stations I made a point of encouraging officers commanding units and formations to apply to the R.E. for assistance, and instructed my own officers to keep units informed of the progress of engineer works, so that the troops might realize we were doing our best. Further, I found that the somewhat inexperienced Division officers we had to employ were helped very much by a personal visit from headquarters, and that many small misunderstandings were avoided by a personal visit. I, therefore, from my first introduction to the Command, definitely allotted two or sometimes three days in the week to inspection work away from headquarters. To enable me to do this it was essential that I should have a deputy at Headquarters who could carry on the work in my absence and ensure that there was no accumulation of arrears, and I was extremely fortunate in having the assistance in this capacity of Col. E. H. Hills, who was a " persona grata " with all branches of the staff. I have dwelt on this point at some length, as the appointment of a Deputy Chief Engineer in the larger Commands has now become a part of the peace organisation of the Army.

With every wish to see as much as possible, it was not possible to visit more than the larger stations or places where some definite want had arisen. But I was immensely helped by the reports of the Inspectors of Q.M.G's services who visited camps and hutments to inspect rations, cooking and barrack organisation, and also by the reports of the D.D.M.S. and his Sanitary Officer. It became a regular routine to pass on to other branches reports of any defects which were brought to notice, and these often resulted in joint visits which saved a lot of correspondence. When I was in the office, in addition to daily interviews with the Major-General of Administration, I made a point of seeing the head of the general staff

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and the A.Q.M.G. every day, while the D.D.M.S. was often in our office. All this interchange became much easier when we were all together at 50, Pall Mall.

R.E. Organisation in the Command.

There was never any question as to the form of the R.E. organisation which should be adopted, as the peace arrangement of C.R.E's and Division officers was admirably adapted for our needs.

What had to be done was a rearrangement of existing areas so as to bring the work within the compass of the capacities of individuals. This arrangement was always going on as the troops in the Command increased and multiplied. In making any change we always endeavoured to make the R.E. areas fit in with the subdivisions of the Command, but owing to the frequent changes of the organisation of the Field Armies already referred to, this was rather difficult.

It was found essential to make each Coast fortress area a definite R.E. unit of administration. This was already the case at Chatham, which had a Chief Engineer, appointed in peace, with C.R.E's under him at Chatham and Sheerness. Dover was more difficult to arrange, as in peace this was the centre of a C.R.E's district, which included the whole of Sussex and the greater portion of Kent. A new C.R.E's area was formed in January, 1916, to include the county of Sussex, and a new area for South East Kent was formed later with headquarters at Ashford. This included the important Shorncliffe area. The work of the C.R.E., Dover was then limited to the area of the Fortress. Harwich in peace was in charge of a D.O.R.E., who was given the full status of a C.R.E. At Newhaven the D.O.R.E. was given full authority as regards work connected with defences, but for the purpose of hutting and works remained under C.R.E., Brighton.

A new district was formed at Hounslow to relieve C.R.E., Woolwich and took over Middlesex (outside London) and West Surrey. Further north, new districts were formed at Bedford for the counties of Bedford, Herts and Northampton, and at Cambridge for the counties of Huntingdon, Cambridge and Norfolk, both of these in relief of C.R.E., Colchester.

Under the C.R.E's each district was divided into three to six Divisions, each with a Division officer in charge, and in some cases an Assistant D.O.

To staff this organisation we collected a body of engineers, including active and retired officers R.E., inspectors of works and civil engineers from all parts of the world. The backbone of the organisation was the retired officers of R.E., and it is difficult to exaggerate the value of their work, while I owe them a deep debt of gratitude for the personal assistance they gave me, which I shall

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never forget. There was no age limit, and many of these officers were much my senior, both in age and experience. Not only was their experience of the greatest value in dealing with the multiplicity of demands from the troops, but their knowledge of the best methods of work and their absolute command of the procedure for its execution, enabled me to rely with confidence that any instructions I might send out would be properly and promptly carried out. Coupled with this there was a capacity for work which never failed.

All the appointments as C.R.E. were filled by R.E. officers on either the active or retired list. Under them, we had Inspectors of R.E. services, several Quartermasters R.E. and civilian Engineers. The Inspectors of R.E. services were at first employed as D.O's, in accordance with a peace organisation which started about 1906. As the work increased, several of my C.R.E's reported that they were overwhelmed by the increase in routine papers, such as bills and contracts, and this difficulty was enhanced by the withdrawal for service overseas of most of the expert subordinate staff. Fortunately here, as in the case of officers, we were able to draw on retired R.E. and on the very valuable group of permanent civilian staff. On going into figures I found that several of my C.R.E's were handling 4,000 bills every month, and it was quite the usual practise for a C.R.E. to reach his office at 6.30 p.m., after a long day's work outside, to find 150 bills waiting his inspection and signature. To meet this want I decided, after consulting the D.F.W., to give each C.R.E. the assistance of an Inspector of Works, and to allow C.R.E's to delegate to these officers much of the routine work connected with contracts and bills and the signing of routine papers.

The arrangements for the custody and record of R.E. stores proceeded on peace lines, and finally each C.R.E. had the assistance of an "Officer in Charge of Stores," usually a Qr.-Mr. R.E. The Qr.-Mrs. R.E. who were not employed with stores were employed as Division Officers, and were generally detailed to Divisions in Fortresses or in barrack areas, where their special knowledge of details was most valuable.

The civilian Division Officers were selected by the D.F.W. at the War Office and posted to the Command, where we distributed them to the best advantage. These gentlemen had considerable engineering experience, some having held high positions in India or the Colonies.

In addition to the above, each C.R.E. had the services of two to four Land agents and House Valuers, and had power to settle small claims without reference to Command Headquarters.

Execution of Work.

In the execution of work outside the Coast fortresses it was necessary at first to rely entirely on contract labour. Inside the

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fortresses there was a small nucleus of military labour available, though this was soon drafted away. In the summer of 1915, as men wounded or sick in the earlier fighting began to drift back to the depots, a letter was received from the War Office suggesting that among these might be found some men with qualifications at a trade who might be formed into "Infantry works companies," of 100 men each under a subaltern, and authorising *one or more* such companies being formed in each Command. On obtaining the names of suitable men from reserve battalions, depots, etc., the first list exceeded 1,000, so the M.G.A. approved at once of the formation of ten companies, and this was rapidly extended to twenty-five companies in all. These were distributed to C.R.E's and useful employment was found for them in such work as levelling aerodromes, preparing sites and making roads.

This development went rather faster than the War Office had intended, but after a conference at the War Office of Chief Engineers of Commands affected, the organisation was approved, with the addition of a Captain to each company and a further addition of a Major for each four companies, who could relieve C.R.E's of the duties usually done by a Battalion Commander.

A reference must also be made here to the very valuable assistance given us by the Road Board under the direction of Mr. Maybury (now Sir H. Maybury, K.B.E.) their Secretary. This body practically acted as contractors for all road services. In busy areas the Road Board appointed representatives called Roads Officers, and C.R.E's and D.O's were authorized to apply direct to these officers for all ordinary road services, whether the repair of a public road or the construction or maintenance of a road in a hutment or camp.

Excluding the above we did most of our work through Contractors of all sorts and conditions.

(*To be continued*).

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TUNNELLING IN THE SAND DUNES OF THE BELGIAN COAST.

By CAPT. H. TATHAM, M.C., A.R.S.M.DIC.

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THIS paper is intended to describe the work of the Tunnelling Companies in the sand dunes of the Belgian coast, where, in the writer's estimation, the engineers had to contend with the most difficult ground, and, therefore, the most interesting on the whole of the Western Front.

The sand dunes in the Nieuport area run along the coast in a belt, from three-quarters of a mile to two miles in width. The sea is very shallow near the coast, and the sandy beach rises rapidly from about half-tide mark to a ridge of sand dunes, which reach an average height of about 40ft. above high-water mark, and gave good cover to many dug-outs constructed in them. On the land side of these is usually a swamp, with little ranges of dunes running parallel to the coast in it; this was called the "Brackpan," and in it most of the wells were sunk. On the further side of this the dunes rise again and again, giving good cover for dug-outs.

This is only really true for the country behind the Oust Dunkirk-Oust Dunkirk Bains Road, as the "Brackpan" dies out in front of the road giving place to a third range of dunes between the other two, which in front of Nieuport Bains all merge into one.

This is best illustrated by a rough section shown in Fig. 1. In the distance will be seen Olympus, which was a large sand dune standing nearly 100-ft. high, and affording an excellent position for the numerous observation posts which were constructed in it.

The work done in this area can most conveniently be divided into three main headings—(1) Wells; (2) Dug-outs, and (3) Sinking Elephant Shelters.

(1) *Wells.*—These were mostly sunk in the "Brackpan" though we actually put down one well on the seashore and obtained fresh water at about high-water level.

The water level in the "Brackpan" was only 6-in. to a foot below the surface, and as all the ground was running sand, the caisson method, which we adopted, was necessary right from the surface.

The largest size of ready-made caisson which we could obtain was only 4-ft. 6-in. in diam., and as this was considered to be too small for the requirements, we had to resort to making our own. These

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consisted of a number of circular sets (made like a "Bull Wheel" of a standard drilling rig) studdled apart and lagged externally with corrugated iron; the bottom 18-in., or cutting edge, was

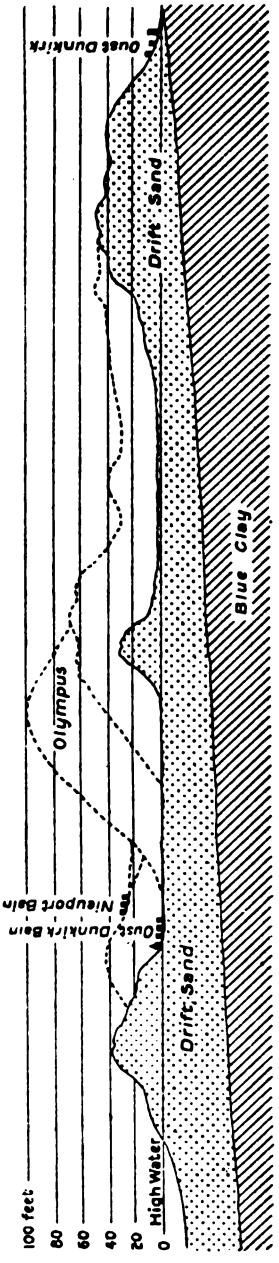

FIG. 1.

strengthened with two iron sets, composed of two angle irons each, bolted together.

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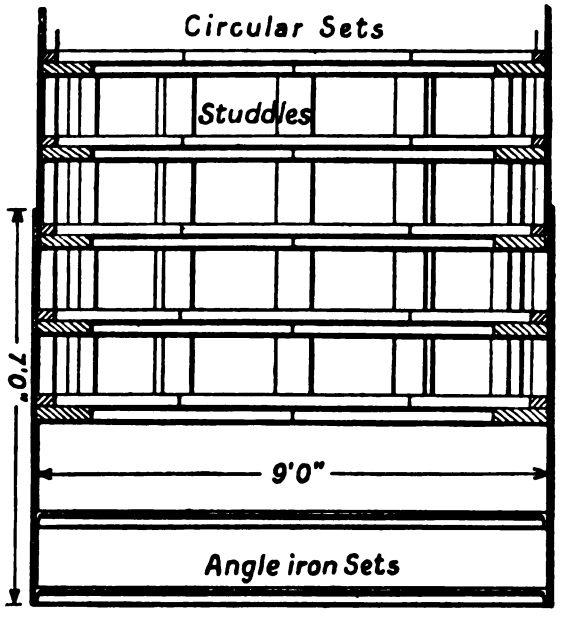
The external diameter was 9-ft., and each section was 7-ft. high, and fitted into the one below. (See Fig. 2).



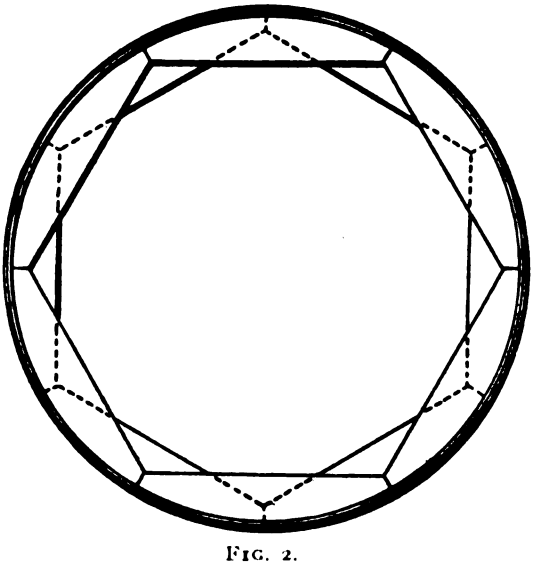


FIG. 2.

The method of sinking was by hand excavation, which gradually allowed the whole caisson to sink; to aid this it was weighted internally with wet sandbags, which completely filled the well,

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with the exception of a small central hole about 2-ft. × 2-ft., extra weight being added by a large heavy superstructure of pit props and sandbags. The sand was hoisted up the central hole in buckets.

Water was very heavy right from the surface, and was at first dealt with by "Dando" hand pumps, but though as many as twenty-four were working at one time in one well, the water beat them at about 12-ft., and the suction pipes nearly filled the central hole, making hoisting extremely difficult.

Finally electric "Pelepone" pumps were installed, worked from a central generating station, and the wells were sunk to 25-ft. which gave about 20-ft. of water. Below this it was impossible to go, as we only had two pumps available for each shaft, with a capacity of 2,000 gal. per hour each, and at this depth they were only able to contend with the water at low tide, as the well made more than 4,000 gal. per hour when the tide was up, though it was nearly a quarter of a mile from the sea.

When the wells reached this depth a close-boarded bottom of 3-in. timber was put in under the last timber set, to prevent the sand from boiling up. Some 15 wells were sunk by this method.

(2) *Dug-outs.*—It was only possible to make dug-outs in sand dunes which rose to the height of 30-ft. above high-water mark as 20-ft. of cover was necessary for their safety; the galleries were 6-ft. high, which allowed 4-ft. for undulations in the top of the dune.

Galleries and Inclines.—The standard size of gallery driven was 6-ft. × 2-ft. 6-in., widening out to 4-ft. for chambers which could not be made wider with safety with the timber available. Though the system employed—piling boards and face boards—is common throughout the world for bad ground, and is probably known to every member of the Institution, a short description may be given to illustrate our method of employing it in this area.

In the first place the sets used were only 4, 5 and 6-in. wide but later, as our miners became more skilled in this method of timbering, sets up to 11-in. wide were used in fairly damp sand.

The dunes mostly consisted of perfectly dry silver sand, which would run if left unsupported for one moment; so bad was it in some places that it would run like water from the smallest hole. For instance, on one occasion one of my men was knocked down and buried over his head in less than a minute by a stream of sand issuing from a hole which could have been blocked by a closed fist could it have been reached in time. As it was he was buried for over an hour and face boards had to be worked back over him before he was freed.

The entrances were driven level into the dunes until 2 or 3-ft. of cover was obtained, then, by inclining the sets in the head and side and top lagging, the level was converted into an incline of 60° dip.

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which was carried on until the sand became damp, which was usually at about 2 or 3-ft. above water level, then the gallery was driven level once more (Fig. 3), which meant that the bottom of the gallery would be about 6-in. above water level, thus taking advantage of the full height of the dune.

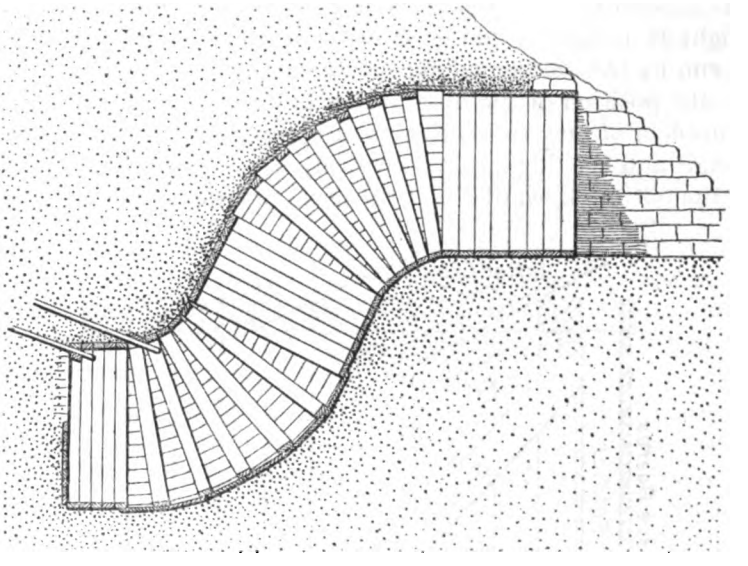

FIG. 3.

The face boards had to be inserted when part way round this bottom bend, and used from this time forward; the piling boards were put in over the first vertical set (or sometimes earlier), and the cap of the previous set lifted to allow them to pass. After this they were set on a false cap resting at an angle on a pair of legs nailed to the permanent legs and driven forward at a fairly steep angle to allow a cap to be put under them on the legs of the second or third set forward.

The face boards were worked forward, one at a time, for the width of one set and held in place by "chocks." When the whole face had been advanced in this manner, the sill was laid and a "soldier" was set (consisting of an upright and sprag) to take the weight (see Fig. 4) while the chocks on one side were removed, and the leg quickly inserted, and held in position by wedges between it and the face boards. Then the operation was repeated and the cap put on, if there was sufficient room below the piling boards; if not they were spragged apart with a stretcher. Each shift drove up their own piling boards, which they put in on the previous day, that is to say, some 9-ft. back from the face. For, if each set of piling boards were driven up as they were finished with, the hammering would disturb

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the face and cause a run. The caps left off to allow the piling boards to pass through were inserted as the latter were driven up out of the way.

Shafts.—For observation posts it was necessary to sink vertical shafts, to connect with the dug-outs, and as suitable places for observing the enemy were also suitable places to be observed by him, it was impossible to do any surveying by daylight and impracticable by night as no lights could be shown, not so much on account of the risks run by the officer making such a survey, but for fear of giving away the position of the observation post. So we were faced with the problem of how to make a good holing between the bottom of our shaft and the dug-out, as obviously it was impossible to timber from the bottom upwards, as is the usual practice in normal ground.

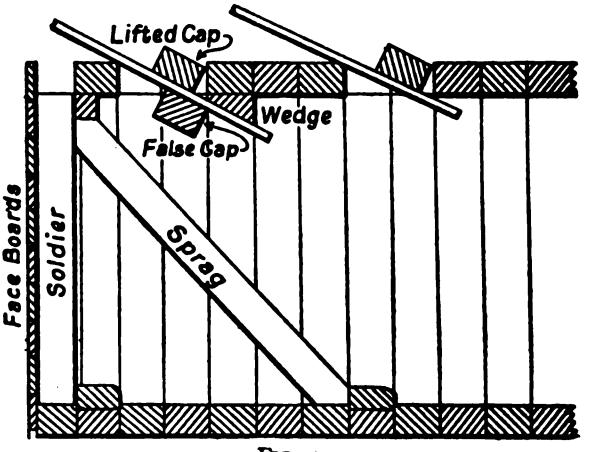

FIG. 4.

This problem was successfully solved by one of our officers, who drove his gallery to a position which he calculated was underneath where the shaft was required, and then let the roof in at dusk, at the same time assembling timber on the surface for sinking an ordinary pile-shaft, the piles being cut long enough to reach the gallery without an inset.

As the fall was cleared away from the gallery, allowing more sand to come in, it ran up to the surface, forming a fairly small vertical hole, at first. The first set was laid over this and the piles quickly placed round and pushed down rapidly, carrying the set with them. All the spoil was removed through the gallery, allowing full scope for the timbermen in the shaft. By this method shafts were sunk 18 to 20-ft. deep in a night, and no signs were left on the surface of the dune in the morning in the shape of wet sand, timber, etc.

Surveying.—One of our great difficulties was surveying in this part of the line. The only instruments provided were a 4-in. prismatic compass and "Abney" level. A number of the holings

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made were bad in direction, and closed traverses never closed. Sometimes back sights and foresights differed by as much as 20° and seldom checked.

This, we discovered, was due to the enormous amount of iron, in the form of shrapnel, shells, etc., just under the surface of the sand, for when certain winds blew, these were exposed in such quantities, that it is no exaggeration to say that one could not put one's foot to the ground without treading on iron. The greater deflections were usually caused by hidden reserves of ammunition buried a few inches below the level of the sand, to conceal them from German aviators and unwary surveyors.

(3) *Sinking Elephant Shelters or Trench Cupolas.*—These were in sections of $\frac{2}{3}$rd of a circle of 4-ft. 6-in. radius, that is to say, that the centre was situated 18-in. above the chord, which formed its base; they were built up of sections 3-ft. wide (excluding lap) and made of heavy section iron, corrugated into 6-in. channels. Each section was composed of two half sections with channel irons bolted on to the upper ends and angle irons to the lower.

A full-size Elephant was 18-ft. 3-in. long, and this was the size which we usually sunk. In the process of sinking, the pressures to be contended with were almost entirely lateral and end pressures, and to resist these the whole structure was built and bolted down to a strong timber frame, strengthened longitudinally by steel I-beams, studdled apart to distribute the lateral pressure, and prevent the whole from bending and breaking its back. The I-beams used were 11-in. × 5-in., and all the timber of the frame was 9-in. × 3in. (except the distance pieces between the studdles in the web of the I-beam, which were 10-in × 2-in.) as nothing heavier was available. (Detail drawings are shown in Figs. 5 and 6.)

The ground was first excavated to an average depth of 6-ft. to give cover for the erecting gang, then the frame and Elephant were built exactly over the spot where they were required.

The sand was then excavated from under the frame from inside, and at first thrown out at both ends, leaving the frame supported on pillars of sand in the corners until last. When the sand had been removed for a foot clear underneath the frame, the four pillars were simultaneously but gradually withdrawn, and the whole structure was allowed to settle down, and then the operation repeated.

When the Elephant had been sunk in this manner some 5-ft., one end was completely, and the other partially, lagged up. Usually one end of the Elephant was to be connected to a drive, from a dug-out, which had already been driven to within a foot of the final resting place of the Elephant, and the other end was to be connected to an inclined entrance, which was to be constructed after the Elephant had reached its final depth. (See Fig. 7.)

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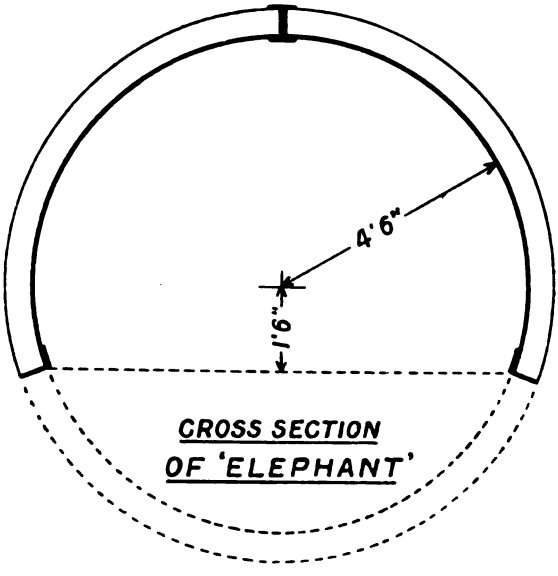
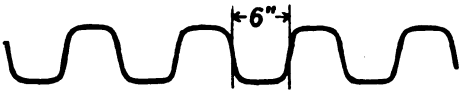
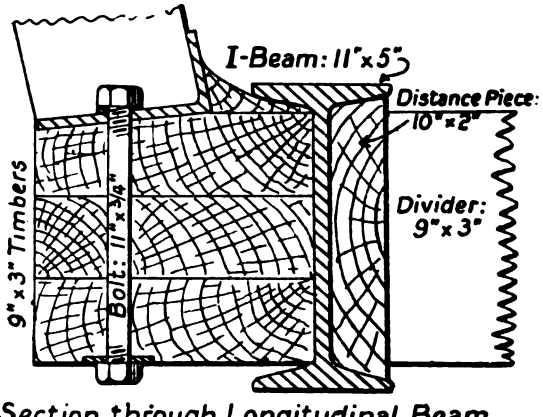
In this case the following method of lagging was found to sa
much time and trouble. A set, 5-ft. 9-in. × 2-ft. 6-in. of 6-in.
3-in. timber, was placed on each of the end dividers and in the la





Corrugations shown on enlarged scale



Section through Longitudinal Beam.

FIG. 5.

corrugation of the Elephant, and vertical lagging set on each su
nailed to the end divider at the bottom and held together at the t

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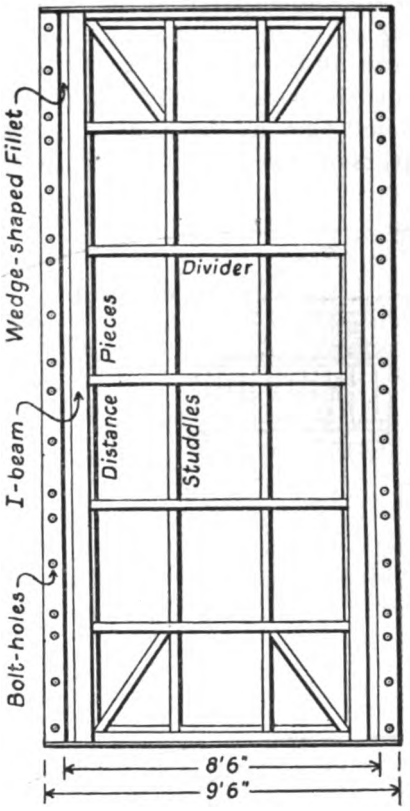
y diagonal braces nailed to them on the inside, which also kept the ts square. The set on the end to be closed was boarded across orizontally with lighter lagging, lightly nailed in place from the



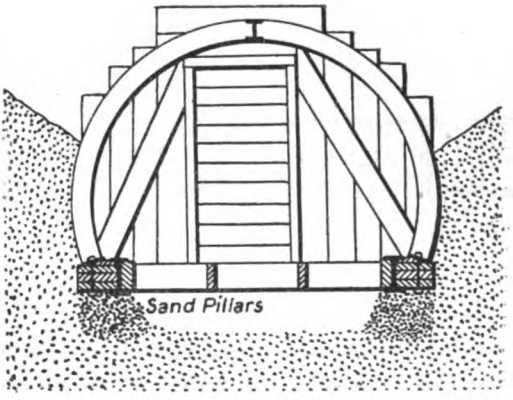


FIG. 6.

utside, so that they could be knocked out from inside afterwards, nd used as face boards.

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The two sets were prevented from collapsing inwards by a 9-in. × 3-in. stretcher running from the one to the other in the crown of the arch, under which pit props, with their feet on the frame, were set to strengthen the roof and hold this stretcher in position. (See Fig. 8.)

From then onwards all the sand excavated was taken out to one end only, and as much as possible built on top of the Elephant. In order to keep this end open as the Elephant sank, Canadian mud scoops, drawn by pairs of mules, were used with considerable success.

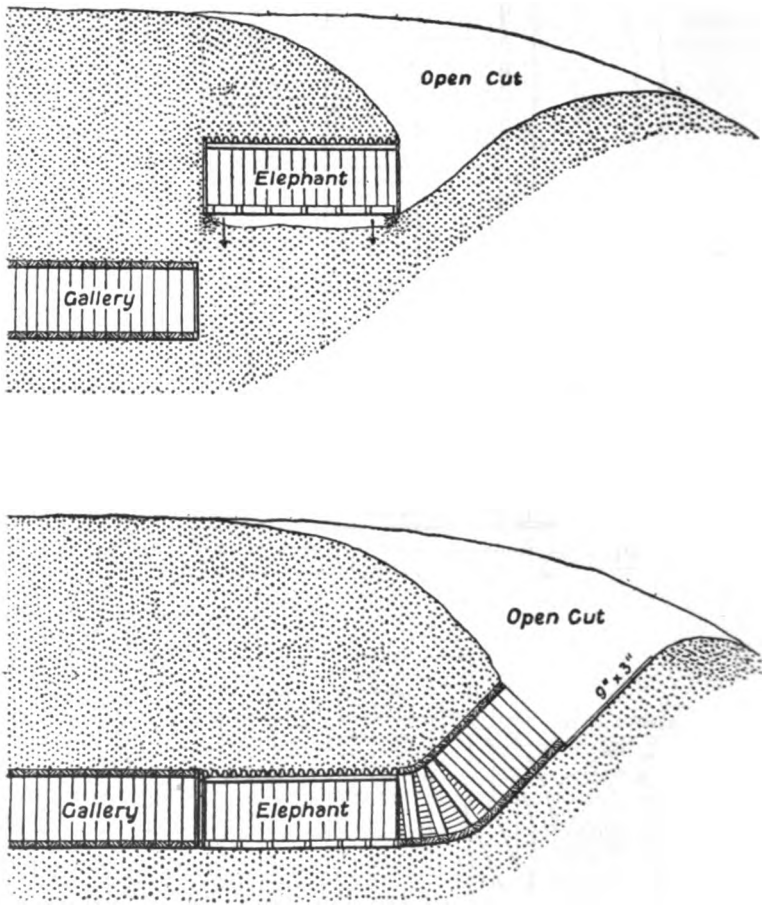

FIG. 7.

Towards the end of the operation the incline became too steep to use these efficiently, and the sand had to be shovelled up from bench to bench.

When the Elephant arrived level with the gallery, which was determined by driving an iron rod through the sand between the

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lagging, the sinking operations ceased and sand was well grouted in under the frame to prevent settlement.

The closed end was next opened up and connected with the gallery, and then the incline was built up from the bottom, and mud scoops were again employed with great advantage to replace the sand.

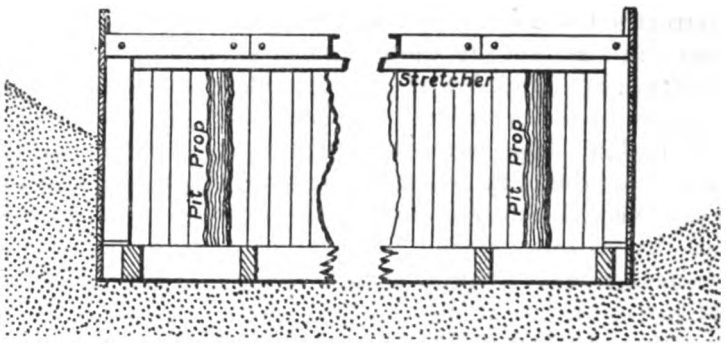

FIG. 8.

By this or similar methods, varying only in detail, a large number of Elephant shelters were sunk in the area to a depth giving from 18 to 25-ft. of cover, and thus overcame the difficulty of chambering in sand.

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ENGINEERS IN THE RETREAT TO CORUNNA.

By Brevet-Major R. H. Dewing, d.s.o., m.c., R.E.

The retreat to Corunna is not a bright page in the story of the Corps. Fortescue in summing up the campaign says " the destruction of the bridges . . . . failed with discreditable frequency through the inexperience of the engineers. Matters which to the French were elementary knowledge were absolutely strange to the British."

Possibly for this very reason the engineer work of this period is dealt with very sketchily in most of the accounts of the operations, and all that is now possible is to piece together such disjointed details as are to be found amongst the numerous stories of the retreat.

When we come to consider the conditions under which the retreat was carried out, the small number of engineer personnel with the army and the inadequacy of the training they had received before proceeding to the Peninsula, we cease to wonder at their failures. Rather we are amazed that under the circumstances so much work was done and any successes at all were achieved.

The conditions under which the work had to be carried out appear fairly clearly in the narrative which follows. What we are told in detail of one or two episodes is probably true of a great many others, of which detailed accounts are lacking.

The total engineer personnel with Moore's army of 25,000 men numbered about 14 Royal Engineer Officers and 34 rank and file of the Military Artificers. In our Army to-day the Royal Engineers number about one to every thirteen rifles; at its apex during the Great War the proportion rose to one to every seven rifles. Sir John Moore had one engineer to roughly five hundred rifles.

The officers of the Corps at that time passed as cadets through the R.M.A. at Woolwich; but they underwent little practical instruction there likely to be of any value to them on service. " They were sent on service without ever having seen a fascine or gabion, without the smallest knowledge of the military passage of rivers, of military mining, or of any other operation of a siege, excepting what they might pick up from French writers."(1)

Among the Royal Engineers who served in this campaign were several who rose superior to these handicaps. Fletcher, afterwards of Torres Vedras fame, was the Commanding Engineer. Charles Pasley was serving in the rank of Captain, and John Fox Burgoyne in that of Second Captain.

(1) Report by Sir Chas. Pasley. See Porter's History of the Corps of Royal Engineers.

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The Military Artificers for the force were provided by drafts grudgingly supplied from the companies of that Corps which occupied permanent stations in England, Gibraltar and the West Indies. The state of vegetation into which these Companies naturally degenerated, and the purely garrison duties on which they were employed, were not conditions calculated to prepare the men for service in the field.

Though practically all the Military Artificers available in Spain at the time were with Sir John Moore's Army, their meagre numbers made any organisation in companies quite impossible, and they were distributed through the force in small detachments of a few men each. Under these circumstances it was necessary to depend very largely on infantry working parties for labour, even of a semi-technical nature.

For the purposes of this sketch it is enough to follow the operations from December 23rd, 1808. On that date the greater part of Moore's Army was concentrated at Sahagun, whither he had moved forward preparatory to attacking Soult at Carrion and Saldana.

With Moore were Lord Paget's Cavalry Division and the divisions of Sir David Baird, Sir John Hope, and Lt.-Gen. Fraser, the Reserve Division under Maj.-Gen. E. Paget, and the two Light Infantry Brigades under Crawfurd and Alten.

On the 23rd Moore received news which led him to cancel his intended offensive against Soult, and issue orders for withdrawal westwards. About noon on the 24th, when the first of Moore's divisions started back from Sahagun, the great retreat had begun.

Baird's Division moved by the northern road to cross the river Esla at Valencia de Don Juan. Hope, Fraser and E. Paget moved via Mayorga, and by the 27th were safely across the Esla at Castro Gonzolo, leaving Crawfurd's brigade to cover the bridge until Lord Paget's cavalry, which had been holding off superior numbers of French cavalry, had withdrawn through it. The cavalry finally withdrew through Crawfurd's Brigade on the 28th (2).

Meanwhile Burgoyne had been sent back to prepare the bridge at Castro Gonzolo for demolition. The road here was carried across the Esla on a bridge of some ten or twelve narrow stone arches, the solid masonry of which proved difficult to cut.

The work was not begun until the 27th and was then carried out in torrents of rain and snow by men of Crawfurd's light infantry, while the rest of the brigade held a covering position on the east bank.

It had at first been intended to cut a single arch, but later it was decided to cut two arches and then blow up the central pier between them.

(2) Oman. Napier says 27th.

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From Napier's account it appears that the actual cutting of the arches was done by manual labour, powder only being used for the pier. This possibly explains the inordinate time taken over the demolition, for the preparations were not complete until early on the morning of the 29th.

Indifferent equipment may also have contributed towards the delay, for Captain Charles Boothby, R.E., who was down at the bridge shortly before it was destroyed, notes in his diary that "The teeth of the cursed saws refused to do their duties, and hours are spent in sawing the woodwork."

When at last all was ready the troops withdrew silently from the heights on the left bank, where they had been in contact with the French Cavalry for the past twenty-four hours, and passed across the broken arches on planks placed over the gaps.

The darkness of the night, the noise of the storm and the roar of the flooded river combined to conceal the withdrawal from the enemy, who did not interfere in any way.

When all were safely across Burgoyne fired the charge and demolished the central pier successfully. It was not until the 30th that the French restored the bridge sufficiently for the passage of artillery.

While the French pursuit had been held up at Castro Gonzolo Soult had begun to move by the more direct route from Carrion via Mansilla on Astorga. Romana's Spanish force at Mansilla failed to break the bridge at that place, and, though criticism of this failure does not come well from the English who themselves failed so often in their own demolitions, the danger of being cut off at Astorga to which Moore was thereby exposed forced him to hasten his retreat.

Our own historians make no mention of demolitions between Benavente and Astorga, but if we may accept the story told by Baron de Marbot it would seem that our Sappers suffer an injustice here.

De Marbot was at that time a Captain on the Staff of Marshal Lannes, and he recounts that in the course of the French pursuit from Benavente to Astorga on December 31st their men were five or six times compelled to strip, place their arms and clothes on their heads, and go naked through the icy waters of the streams, as all the bridges had been broken by the English.

About this time a certain number of the Royal Engineers, and among them some of the more experienced ones, were despatched on various reconnaissances. The number of R.E. Officers remaining for the vital work of demolition at the rear of the retreating army was thus further reduced.

Major Fletcher was sent to Ferrol and Corunna to report on the capabilities of those places for the embarkation of troops. He reported on January 5th that he had examined the ground between

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Ferrol Harbour and the bridge at Puente de Humo and had found no favourable ground where a vanguard could cover the embarkation. In a second report he wrote much more favourably of Corunna.

These reports, together with that of Burgoyne, who had been sent on a similar mission to Vigo, reached Sir John Moore at La Herrerias and decided him to make his embarkation at Corunna.

Captain Carmichael Smith had been sent to report on positions between Astorga and Corunna where the Army might find favourable ground for a stand. He reported that a position west of Cacabellos was by far the strongest position between Astorga and Villa Franca.

Another "very sensible Officer of Engineers" (3) reported on January 1st from Puebla de Senabria, whither he had been sent to promote the defence of the place, that little was to be expected of the Spaniards there, whose attitude was a purely passive one, relying on "hopes of protection from God and the English Army."

At Astorga Crawfurd's and Alten's Brigades separated from the main army to march via Orense to Vigo.

The main army continued on the road to Villa Franca, where it arrived on January 1st.

No mention has been found of any further attempts at demolition of bridges east of Villa Franca. Sharp fighting took place on the 3rd at the crossing of the River Cua at Cacabellos, which would have seriously interrupted any preparations for the demolition of the bridge there. The time gained by the Reserve Division on the Cua was probably used by the engineers for the concentration of their efforts on the bridge on the western outskirts of Villa Franca.

The Army had halted for two days at Villa Franca, and here discipline completely broke down. Already on the retreat disorder had been common enough; very severe orders against indiscipline had been issued, and drastic punishments had been carried out, but these were not enough. Bitter disappointment at being forced to turn their backs on an enemy whom they had been confident of beating, the laxity of some of their officers, and the hardships of the retreat now combined to destroy the last vestiges of discipline in many of the battalions. Many of the troops got entirely out of hand and devoted themselves to plunder, murder and drunkenness.

The main body marched on the 3rd leaving drunken stragglers in the streets behind them. The story told by a Commissary who remained in the town till the last gives a picture of the state of affairs at the tail of the column.

"On the afternoon of the 4th January (4) some sharp firing, intermingled with gunshots was heard just outside the gates of the town. Many of the rearguard marched in and told us as they went by that things were very warm out there . . . . A Sapper

(3). Capt. Charles Boothby, R.E.
(4) 3rd, according to most authorities.

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Officer then galloped through the streets shouting that by 6 o'clock everybody was to be over the bridge as it was then to be blown up. Now the uproar began! Women, children, the sick, and baggage waggons all tried to get across at once. The troops making their way across by force slowly marched away regiment by regiment, while other troops fresh from the battle outside, arrived in the town . . . .

" The sun sank towards the horizon. The fire of the skirmishers became so fierce at the entrance to Villa Franca, where I happened to be standing, that the bullets rattled on the surrounding roofs. The rearguard poured in in masses. One or two Sapper Officers ran hither and thither, urging everybody to proceed to the bridge, for the gate of the town was not going to be held after the bridge had been blown up. Now all who still happened to be in the town made haste to escape . . . .

" On the bridge, which was somewhat elevated and narrow, I and my horse were carried shoulder high by the throng, and were frequently almost crushed by the ammunition carts. At last I reached the other side. . . . Night soon fell, and we marched slowly forward in the darkness. A loud report in the direction of Villa Franca announced that the bridge had been blown up, and at the same moment the horizon was illuminated as if the town were in flames."(5)

Unfortunately the Commissary's conclusion was wrong, for the demolition had actually failed.

On the 4th (6) the Reserve Division reached Nogales after a forced march. On the 5th they marched on to Santa Maria de Constantin.

The engineers made two unsuccessful attempts to blow up the bridge at Puente Ferreira. (7) Perhaps their powder did minor damage, as the French cavalry are said to have been somewhat delayed at the bridge.

Napier's explanation of this failure reads too much like special pleading to exonerate the engineers. He says the failure was of little consequence " for the river was fordable above and below, and the general was unwilling, unless for some palpable advantage which seldom presented itself, to injure the communications of a country he was unable to serve; the bridges also were commonly very solidly constructed, and the arches having little span, could be rendered passable again in a shorter time than they could be destroyed. Moreover the road was covered with baggage, sick men, women and plunderers, all of whom would have been thus sacrificed."

These arguments might justify the General in ordering no demolitions to be attempted, but in no way explain failure when charges were actually laid and fired.

(5) Schaumann. "On the road with Wellington."
(6) Oman and Fortescue. Napier says 5th. (7) Fortescue.

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On the evening of the 5th yet another failure was experienced. At Constantin the road crossed a deep sunk river by a stone bridge, but the attempt of the engineers to blow up the central arch was unsuccessful.(8) Paget's rearguard held the French in check on the line of the river until nightfall.

On the following day the Reserve reached Lugo, where Moore had halted his main body on a position east of the town.

Somewhere between Constantin and Lugo the Commissary who has already been quoted, passed across "a magnificent bridge composed of three arches, which looked like an aqueduct, and led across an abyss through which foamed a mountain torrent. Both the ravine and the bridge were regarded by many as a bulwark which, the moment the bridge had been blown up, would protect us for a few days from the French, who were hard on our heels."

There he saw an officer and a party of sappers who had bored two holes into the centre of the bridge, and were preparing to blow it up; but this charge, too, was destined to fail.

The Commissary says that " a good deal of fun was poked at the English Sapper Officers, owing to their obvious incapacity and lack of skill; and it was deserved, for it was unpardonable and caused our army an incalculable amount of harm."

In front of Lugo Moore's Army stood throughout the 7th and 8th in the hope that Soult would attack. The French Marshal decided to wait until he was concentrated in superior force before committing himself against the strong English position.

On the night of the 8th-9th Moore continued his withdrawal. Although careful preparations had been made to ensure that units should be able to move back by night without loss of direction, pitch darkness and a severe storm combined to obliterate the marks which had been put out to guide them, and many lost their way.

It is a relief to find that in spite of the resulting confusion the sappers succeeded in making a good job of the destruction of the bridge over the River Minho about 8 miles north of Lugo. (9) The French pursuit was thereby delayed on a day on which every hour's respite was of value, and it was not until noon on the 10th that Soult's engineers completed its repair.

The march of the Army from Lugo to Betanzos was marked by indiscipline and disorder even worse than any that had occurred earlier. This is enough to account for failure to carry out Moore's orders for the destruction of the bridges over the Rivers Ladra and Mandeo on the 9th. Powder spoilt by the rain and lack of skill in the laying of the mines are given as contributory causes.

The Army halted at Betanzos, still covered by Paget's staunch Reserve Division, until the 11th, when the main body withdrew to Corunna and the rearguard to El Burgo.

(8) Oman. (9) Fortescue.

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At Betanzos there were two bridges, the one a stone structure of fourteen arches across the Mandeo and the other of timber, across the Mindo. The line of retreat lay across the latter, but the Mandeo bridge was also mined ready for blowing up.(10)

Sappers were still at work on the wooden bridge on the afternoon of the 11th when the French arrived on the scene and interrupted them. A battalion of the 28th drove the enemy's skirmishers back, but even then the mines failed, and so little damage was done that two French divisions were able to cross the bridge before dark.(11)

The withdrawal on the 11th brought the army to the west bank of the Mero, the last river to be crossed in the retreat. Here at last demolitions were carried out thoroughly.

On the night of the 11th the bridge by which the *chaussée* crossed the Mero at El Burgo was successfully blown up. The French needed forty-eight hours to repair it sufficiently for infantry, and it was not until the afternoon of the 14th that they got guns across.

Simultaneously with the destruction of the El Burgo bridge Lieutenant Davy R.E. blew up another bridge across the same river at Cambria.

This final success was accompanied by tragedy, for Davy lost his life in the explosion. Perhaps, as Napier suggests, mortified by previous failures, he remained too near the mine in his anxiety to ensure success; perhaps he lost his life through simple ignorance of the precautions necessary when firing the train of a mine.

In either case his death stands as a proof that, whatever may have been the defects in the training of the Corps, its spirit at least stood as high as ever.

With the destruction of the two bridges over the Mero the main work of the engineers was over. Doubtless it was an engineer who lighted the train to blow up the great store of 4,000 barrels of powder at Corunna, whose explosion caused a shock which has impressed every writer on the campaign. There was work too to be done in strengthening the defences and erecting batteries at Corunna; but the main work was done, and, it must be admitted, badly done.

Yet out of this evil came good. So impressed was Pasley with the shortcomings of the Corps that he did not rest from urging the need for reform, until in 1812 his importunity was rewarded, and the Royal Engineer Establishment at Chatham came into being.

(10) Schaumann. (11) Fortescue.

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THE POST-WAR ACTIVITIES OF THE ROYAL ENGINEERS.

(*TRANSPORTATION BRANCH.*)

By Major L. C. Owen, d.s.o., R.E., D.A.D. Transportation.

This article is intended to supplement the article, under the same general heading, which appeared in the *R. E. Journal* for September, 1924, but in which only a passing reference was made to the Transportation Branch of the Corps.

Following the lines adopted in that article, transportation activities in India are not included.

1. Regular Peace Establishments (Home).

In 1912 the R.E. Railway Depot at Longmoor consisted of the 8th, 10th and 53rd Railway Companies, R.E. The 53rd Company was, however, disbanded in 1913, leaving available in 1914 the 8th and 10th Companies only, each with a peace establishment of three officers and 106 other ranks, of whom 30 were recruits at Chatham.

The Railway Depot has now been renamed the Railway Training Centre; and a peace establishment has been authorised for it, consisting of 15 officers and 412 other ranks, exclusive of officers under instruction at Longmoor or on main line railway courses, and of recruits at Chatham.

The Training Centre includes .—

(*a*) Headquarters.
(*b*) 8th (Composite) Railway Company, R.E.
(*c*) 10th (Depot) Railway Company, R.E.

The Headquarters includes the administrative and instructional staff for handling both Regular and Supplementary Reserve Units: the 8th Company, in addition to its own peace establishment includes the peace nucleus for the other regular railway units of the Expeditionary Force: whilst the 10th Company includes all personnel required for running the Military Camp Railways at Longmoor and at Larkhill, both in peace and on mobilization after the despatch of the railway units of the Expeditionary Force.

Up till December, 1923, the Catterick Camp Railway was also run by a detachment from the Railway Training Centre, but this has now been handed over to be worked by the London and North Eastern Railway as the agent of the War Department.

Since April, 1924, the Railway Training Centre has been kept well up to establishment strength, as far as numbers are concerned,

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which is a great improvement on the state of affairs that existed at the old Railway Depot before the war. At that time, owing to the very reduced numbers actually available, very great difficulty was experienced in carrying out the military and technical training of the companies, and at the same time keeping a minimum service of trains running on the Longmoor Camp Railway.

As regards the trades establishment, the field for railway trades is necessarily so much smaller than that for general corps trades that it has been found necessary during the collective training season to give every non-railway tradesman a general grounding in some railway trade. In addition a series of special courses with the main British Railway Companies have been recommended for selected N.C.O.'s, with a view to providing suitable N.C.O. instructors at the Railway Training Centre. These arrangements have had the effect of considerably improving the "trades position."

As regards the training of officers, two young officers are sent each year from the S.M.E. to the Railway Training Centre, to which they are posted for a period of three years. During this time they do two periods of six months on a civil Railway system, with an intervening period of six months to a year at the Training Centre. Whilst with the civil Railways all officers are instructed in railway maintenance, and in addition either in operating or mechanical work.

2. Regular Peace Establishments (Abroad).

(*a*) There is at present a small establishment of 12 officers and 85 other ranks allowed for the British portions of the Inter-Allied Rhineland Railway Commission and its Sub-Commission at Cologne.

The duties of the Commission and the Sub-Commission are to supervise the German Railways in the occupied territory, and as far as the Cologne Sub-Commission is concerned, in the British zone in particular, so as to ensure that the railways in that zone are maintained to meet any possible Allied requirements, and to prevent as far as possible any militarization by the Germans of the railways in occupied territory in contravention of the Treaty of Versailles. This work entails the close supervision of locomotives, rolling stock and permanent way, and opportunities are thus available for training the British railway personnel on an open line railway.

(*b*) It is hoped to arrange for small parties of officers and N.C.O.'s to be employed on survey or construction work on Colonial Railways, as was done in Nigeria in 1908-1911 on the Baro Kano Railway. At the time of writing tentative arrangements are in hand for two officers and six N.C.O.'s to be employed on the railways in Kenya Colony.

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3. Transportation Requirements for War.

In 1914 the only regular transportation units available for the Expeditionary Force consisted of the 8th and 10th Railway Companies, R.E., each of four officers and 250 other ranks. At that time there was definitely no liability to find large numbers of transportation troops, as it had been laid down that the French would carry out all the transportation services required for the B.E.F.

As a result, however, of the experience of the War and the recognition of the vital importance of transportation, accentuated by the development of aircraft, heavy artillery, tanks, mechanical transport, etc., etc., all of which bring increasing demands on the main line of communication transportation services, it has been realised that considerably larger numbers of trained transportation units must be available early for the Expeditionary Force of the future. From the point of view of national economy, it was not desirable to raise all these units on a regular basis, but, as the majority of the personnel required are for construction or maintenance, operating and workshop duties, it was agreed that men enlisted on a militia basis from civil railway employ would be eminently suitable.

It was, therefore, decided to try to raise in peace time, from the employees of the main British Railway Companies, a certain number of transportation units to form part of the Army Supplementary Reserve and to work in war time alongside the regular units for which the 8th Railway Company, R.E. forms the peace time nucleus.

4. Procedure Adopted for Raising Transportation Units of the Supplementary Reserve.

(*a*) It was decided that, in view of the post-war grouping of the British Railways into four main groups, the most suitable way to raise these units would be with the co-operation of the General Managers of these Groups, and under the ægis of the civil railway organisation.

A meeting was, therefore, held at the War Office in May, 1924, between the Quartermaster General and the General Managers, at which the latter promised to give their utmost assistance to the raising by each of the groups of certain definite units. It was proposed that each unit should be composed of officers, N.C.O.'s and men drawn entirely from the employees of any one group, as by this method it was hoped to create an "esprit de corps" in each unit from its formation.

The units which it was desired to raise in the first instance, had already been decided on by the War Office, and, with the con-

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currence of the General Manager, the allocation of these units to the various groups was laid down on the following general lines :—

(*a*) Platelaying and operating units to the London and North Eastern and Great Western Railways.

(*b*) Docks units to the London and North Eastern Railway.

(*c*) Workshops and railway telegraph units to the London, Midland and Scottish Railway ; and

(*d*) Stores units to the Southern Railway.

It was found impossible to raise a Railway Bridging unit from any one group, but to maintain the " esprit de corps " idea it was agreed that each group should raise one section of this unit, the Great Western Railway, in addition, providing the personnel for the unit headquarters.

(*b*) The General Managers were then asked to nominate officers from their staff to be the first commanding officers of the various units, preference to be given as far as possible to those with previous military experience.

A further meeting was held in September, 1924, between the Assistant Director of Transportation, War Office, and these Commanding Officers to discuss preliminary details with regard to :—

(i) method of selecting officers and other ranks to complete units to establishment ;

(ii) location of headquarters and the general distribution of each unit ;

(iii) arrangements for enlistment, training, etc., etc.

It was decided that, as a first preliminary to the enlistment of other ranks, it was most desirable that uniformity should be obtained as far as possible with regard to the facilities to be given by the various Railway Companies to their employees to enlist, obtain leave for drills and annual camp training, etc. It was, therefore, arranged that a small Committee should be formed, consisting of one officer from each Railway Company, representing the Commanding Officers of the various units being raised by their Company, together with an officer from the Transportation Branch of the War Office, and that this Committee should draw up a draft general circular and forward it to the various General Managers with a view to an agreement being reached on any points at issue, and uniform instructions being issued to all concerned.

The Railway representatives on this Committee were :—

Lieut.-Col. V. M. Barrington Ward, D.S.O., for the L.N.E.R.
Major A. S. Quartermaine, M.C., for the G.W.R.
Major J. V. Denning, M.C., for the L.M.S.R.
Major H. A. Short, M.C., for the S.R.

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These officers rendered the greatest assistance both on this Committee and in the subsequent preliminary work of recruiting and organising the units, and the Transportation Branch of the War Office are very much indebted to them for their help, which involved a great deal of voluntary work outside their official duties.

(c) A general circular for issue by the General Managers had been agreed to by the end of the year, the first one actually issued being that of the London and North Eastern Railway on December 20th, 1924.

Unfortunately, owing to a misunderstanding on the part of some of the Trade Union leaders as to the liability of Supplementary Reservists to be called up for military service during a civil disturbance, particularly as "railway strike breakers," the L.N.E.R. circular led to another being issued by the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen, advising their members not to join.

This misunderstanding was subsequently explained, and the circulars of the other three Railway Companies were issued about May 1st, 1925, and the formation of all units was proceeded with as rapidly as possible.

5. Organization and Administration of Supplementary Reserve Units.

The personnel is composed of two categories, B and C, of which Category B have to carry out training in peace time on the same general lines as personnel of the Territorial Army, whilst Category C are recruited in peace time and get an annual "retaining fee" bounty, like Section D of the Regular Army Reserve, but are not liable for any peace time training.

It was decided when the Transportation units were first being raised, to put all the personnel of the Construction units in Category B, but for other units to only include in Category B the officers and senior N.C.O.'s. This was done, as it was considered necessary to give *all* construction personnel technical training under military conditions in such work as rapid platelaying, demolitions, etc., whilst the personnel of other units, such as operating and workshop companies, etc., needed no special technical training, although a nucleus, even if the whole could not be made available, would require military training to enable them to administer, drill, etc., their units.

Each unit has up to the present been linked up, as far as Category B personnel are concerned, for administrative purposes with a County Association of the Territorial Army, through whom, under the Command concerned, all arrangements for the enlistment, clothing, drills, musketry, etc., of personnel are made. Category C

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personnel are enlisted through the Regular Army Recruiting agencies and are administered by the Officer i/c R.E. Records.

6. TRAINING OF SUPPLEMENTARY RESERVE UNITS.

As stated in the previous paragraph, the military individual training, including drills, musketry, etc., is carried out under Territorial Army arrangements, but the Commandant, Railway Training Centre, at Longmoor, is responsible, under the Transportation Branch of the War Office, for the technical training of personnel.

It had been hoped that all the Railway Recruiting Circulars, referred to in paragraph 4 (*c*) above, would be issued in January, 1925, and that recruiting and the initial organisation of the units could be carried out between then and June. A programme for the technical training of both regular and reserve units at the Railway Training Centre was, therefore, drawn up, under which the reserve units would do their annual camp during the months of June, July and August. Owing to the delay in the issue of the circulars and consequently in recruiting, this programme had to be amended, but it was still found possible, commencing on July 8th with No. 1 (L.N.E.R.) Platelaying Company, to carry out the annual camp training for all construction units and the Category B portion of other units. During this training, the construction units carried out certain technical work, and in addition all units were given instruction in collective training, unit administration and the organisation of the army transportation service. The attached table shows the establishments, Categories B and C, of the various units, the numbers attending annual camp, and the actual strengths of units on September 28th, from which it will be seen that, considering the short time available since it was definitely decided to launch the formation of these units and the difficulties experienced in the initial recruiting, organisation and administration, very considerable and satisfactory progress has been made. For this great credit is due to the Officers Commanding the units and their headquarters personnel, and to the Railway Companies and County Territorial Associations concerned for their co-operation. As a result of this year's annual camp training having been adhered to in spite of the difficulties experienced, it is hoped that all units will be practically up to strength by the end of the financial year, and that full numbers will be able to attend camp next year.

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SUPPLEMENTARY RESERVE R.E. (TRANSPORTATION).

Numbers present at ANNUAL TRAINING, 1925, and ACTUAL STRENGTH on 28th September, 1925.

Unit.	Establishment.						Numbers at Annual Training Category B.		Strength on 28th September, 1925.					
	Category B.		Category C.		Total.				Category B.		Category C.		Total.	
	Offrs.	Other ranks.	Offrs.	Other ranks.	Offrs.	Other ranks.	Offrs.	Other ranks.	Offrs.	Other ranks.	Offrs.	Other ranks.	Offrs.	Other ranks.
No. 1 (L.N.E.) Rly. Platelaying Co.	6	264	–	—	6	264	6	171	6	197	–	—	6	197
No. 2 (G.W.) Rly. Platelaying Co.	6	264	–	—	6	264	6	96	6	108	–	—	6	108
No. 1 Railway Bridging Company	6	264	–	—	6	264	6	94	6	95	–	—	6	95
No. 1 (L.M.S.) Adv. Rly. Workshop Co.	3	13	–	256	3	269	3	7	3	10	–	111	3	121
No. 2 (L.M.S.) Base Rly. Workshop Co.	4	13	–	254	4	267	3	9	3	12	–	171	3	183
Headquarters Railway Stores Depot.	2	4	–	5	2	9	2	2	2	2	–	2	2	4
No. 1 (Southern) Rly. Stores Co.	5	13	–	239	5	252	2	5	2	5	–	41	2	46
Headquarters Rly. Operating Group	1	2	–	9	1	11	8	42	1	1	–	8	1	9
No. 1 (L.N.E.) Rly. Operating Co.	4	24	–	298	4	318			4	22	–	259	4	281
No. 2 (G.W.) Rly. Operating Co.	4	24	–	298	4	318			3	21	–	120	3	141
Headquarters Docks Group	2	2	–	8	2	10	2	2	2	2	–	6	2	8
No. 1 (L.N.E.R.) Docks Company	11	23	–	107	11	130	11	22	11	22	–	70	11	92
No. 1 (L.M.S.) Railway Telegraphs	6	181	–	—	6	181	2	37	3	42	–	—	3	42
No. 3 (L.N.E.) Railway Operating Co. (Category "C" Units.)	—	—	4	318	4	318	—	—	—	—	1	169	1	169
No. 4 (G.W.) Railway Operating Co. (Category "C" Units.)	—	—	4	318	4	318	—	—	—	—	1	146	1	146

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NOTES ON DUTIES OF ADJUTANTS OF TERRITORIAL ARMY AS REGARDS TRAINING, WITH SPECIAL REFERENCE TO R.E. WORK.

By MAJOR-GEN. G. WALKER, C.B., C.B.E., D.S.O.

1. The duties of an Adjutant of a Territorial Unit are broadly defined in the Regulations for the Territorial Army. The object of these notes is to indicate the methods and the spirit in which those duties should be carried out. The first essential is that the Regular Officer, who is serving as Adjutant of a Territorial Unit, should make himself thoroughly acquainted with the local conditions under which his unit is serving. He must visualise their difficulties and never forget that these citizen soldiers are devoting a great deal of their spare time, and some of their money, gratuitously, to the service of the State. All his work must be carried out with this fact kept clearly in view.

2. It will, therefore, be his business not only to teach the unit its military business but to teach it in such a way as shall not interfere unduly with the civil activities of the Officers, N.C.O's and Men. His instruction must also be organised and carried out in such a way as to impress his pupils with the fact that he has a thorough knowledge of the work himself, and also to engender in them the enthusiasm for the responsibilities which they have undertaken, which is essential to the attainment of any measure of real efficiency. The human side of the picture can never be put aside. A good adjutant must look upon himself as a man whose duty it is to help everyone to learn. He must not merely be a soulless administrator of regulations.

3. As regards detailed methods of instruction apart from routine, it is almost impossible for one officer to try to teach everyone himself. The best way for an Adjutant to proceed is to organise classes.

(*a*) Officers. To be taught by himself.
(*b*) N.C.O's. To be taught, under the Adjutant's supervision, by the Sergeant Instructors and Territorial Officers.

In this way a volume of educated opinion will be formed whereby instruction can be more broadly disseminated. In other words the Adjutant should strive to form a body of qualified instructors, rather than attempt to teach every one himself. These classes should be held quite apart from the ordinary drills and can often be carried on by correspondence; practical work being done at

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week-end Camps. This work, however, does not relieve the Adjutant of his responsibility for superintending the work of units on parade, and seeing that the Territorial Army Instructors, either Officers or N.C.O's, are working on the right lines.

4. The Officers' classes should be based upon a definite syllabus. The procedure broadly should be as follows :—

All officers, after they have become proficient in Drill and Weapon Training, must first be given a thorough working knowledge of the *Field Service Regulations*, in order that they may understand the principles and methods on and by which troops fight battles. Following this comes the technical education in Field Engineering. In dealing with officers of technical professions in civil life this work will not be difficult and will largely consist of explaining military equipment and methods of improvisation, and an explanation of the application of engineering science to the necessities of an army. Probably the most difficult part will be the instruction in entrenching. The technicalities are few, but the application to military situations, in agreement with the principles of *Field Service Regulations*, is not so simple. A golden rule to follow is that it is the site, not so much as the details of a trench, that matters. This part of the course must be illustrated by actual schemes on the ground and, if possible, it should be done in consultation with artillery and infantry officers. Broadly speaking, the education of the officer of an R.E. unit must consist in

(*a*) Making him a soldier.

(*b*) Making him a *military* engineer.

These are the principles that govern the training of the regular R.E. officer at the S.M.E., and they should be followed in all branches of the Engineer Corps. In fact, an Adjutant of an R.E., T.A. unit should look upon himself as an exponent of S.M.E. methods shaped to suit local conditions. Practically it will be found that this sort of progressive teaching can only be applied to junior officers. The senior officers are fully employed looking after the men. There should, in fact, always be a small school for last joined officers, who are thoroughly instructed before they are asked to instruct the N.C.O's and men of their units. Refresher classes for all officers should also be formed. A suggested syllabus of instruction for these Schools is attached as an appendix.

5. The classes for N.C.O's should deal with the following :—

(*a*) Drill and manœuvre of small units.

(*b*) Weapon Training and Fire Discipline.

(*c*) Technicalities of Field Engineering.

The junior N.C.O's should receive particular attention, and the system should be the same as suggested for officers above, the object

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of the course being to create good instructors who can pass the instruction on to the men.

6. (*a*) Our training books are now very complete and everyone should be encouraged to read them. Lectures should therefore not partake of the nature from a reading from the book by an instructor, but be a demonstration, pictorially and from experience, of what is written in the books. Nothing is more valuable as illustration than an instructor's personal experience or definite instances from military history.

(*b*) The Adjutant must have a definite programme of lectures and exercises for officers and N.C.O's. This programme should be carried out by lecture, correspondence and in the field—quite apart from the training of the junior ranks in technicalities, which should be carried out in Drill Halls, Week-End Camps and Annual Camps by the T.A. Officers and N.C.O's, under the superintendence of the C.O., Adjutant and permanent staff. It must be emphasised that ocular demonstration by model or diagram is much better than long-winded wordy lectures. We must all clearly understand that we are training units (teams of men) for war, and that we must train the personnel of these teams to each fulfil his particular function in the organisation. We must not muddle up principles and details. Officers and N.C.O's require principles and details, junior ranks details only.

(*c*) In this connection it must be stated that *F.S. Regs., Vol. II*, deals comprehensively with the principles of war, and that all our teaching must be based upon this. The engineer details cannot be dissociated from these principles, as the only office which they perform is to enable the fighting man to make war successfully. In teaching military engineering, everyone should be shown *where* any work is required before he learns what the details are to be.

7. As regards the training in camp.

(*a*) The camp site is usually settled early in the year. As soon as it is settled it is essential that :—

(i) The site should be inspected by the C.O. and Adjutant.

(ii) After this inspection it should be decided what works are to be erected to illustrate the year's work.

(iii) When this has been determined, the Adjutant should make all the necessary arrangements for the supply of the necessary stores to carry out the work properly. It is essential that camp work should all be done with full-sized stores, and not with what may be called semi-model stores.

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(*b*) Lectures in camp should be as short as possible and only deal with the works in execution. General lectures should be given before camp.

(*c*) Some units devote time in camp to physical training. The men get plenty of physical work in camp without artificial training of their bodies. P.T. can be done in Drill Halls, and it is axiomatic that the work in camp should only be such as cannot be dealt with at home.

8. In field units it is essential that *all* officers and all the N.C.O's and Drivers of the mounted branch should have adequate instruction in Horsemastership and the care of harness, both in barracks and in the field. It is not sufficient to just let one individual officer or N.C.O. take complete charge of this department.

9. Technicalities are essential for the military engineer, but it is often forgotten that these technicalities are not much use unless everyone clearly understands how they should be applied in the field. To learn this, co-operation with other branches of the service, both in indoor classes and operations in the field, is essential. A military engineer is the servant of the Army, and unless he knows what the Army is likely to want, he is not likely to supply its needs expeditiously, nor be an efficient servant.

10. In organising all classes of Instruction in the Territorial Army, it is well to organise on the basis of a cycle of 4 years, especially for the men. Officers serve longer, and for them this point may not be so important. The time each year is so short that everything cannot be done within that time. The most that can be aimed at is to make the Territorial soldier's education complete by the end of his service. This must not affect the initial classes of instruction alluded to in paras. 3, 4 and 5 above, as they are essential before officers and N.C.O's are really able to take their places in a unit, but it applies to the larger organisation of unit courses such as Field Defences, Bridging, etc.

APPENDIX I.

SUGGESTED SYLLABUS OF INSTRUCTION FOR CLASSES OF JUNIOR OFFICERS R.E.T.A.

F.S.R., Vol. II.

Chap. I, 1, 2, 3, 9; Chap. II, 10, 11; Chap. III; Chap. V; Chap. VI, 33-38 and 40; Chap. VII.

Lectures on the broad principles involved. The object being to make officers read and digest the book itself and ask questions. Too much detail to be avoided, but, wherever possible, concrete cases to be used to illustrate the lectures.

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Chap. VIII.

General broad principles, special attention being given to t
use of engineers. Lectures on Field Engineering should begin.

Chap. IX.

General broad principles. Siting of trenches on ground an
on paper to be done at this time.

Chap. X.

Broad principles only.

Chap. XII.

Broad principles only.

Chap. XIII, 169, 173, 174, 177, 178, 180, 181, 182, 183, 184, 185, 18
Special attention to Hygiene and Water. Paragraphs o
Manual of Field Engineering referring to be taught at the same tim

Chap. XIV.

Order writing to be practised not only as regards purely military
orders but *also* as regards Engineering Instructions and sketches

Chap. XV.

Supply of Ammunition and Explosives to R.E. Units.

Appendix No. 1.

To be used when teaching Military Bridging and Trench work

Generally.

Instruction in Field Engineering should be given alongside th
Chapter in *F.S.R.* that bears on the particular part of the subject
in hand. The object being to show how the engineer's art work
into the methods of making war.

2. The actual technicalities of Engineering must be taught
separately however.

Officers should be shown how to use the tables of stresses,
weights, etc., given in Appendix V of the *Manual of Field Works*
and in *Military Engineering, Vol. III*, and elsewhere (including
Military Engineering, Vol. I, when it is published).

Those officers who have no technical engineering qualifications
can easily be taught to apply the most commonly used formulæ
(e.g., that for rectangular beams r $\frac{bd^2}{6}$ and for steel joists rAD
and to work out the bending moment of loaded beams; but care
should be taken not to enter into mathematical and statical digres-
sions, and to confine instruction to the use and application of simple
formulae and the tables given in these manuals.

3. Appendix No. 1 *F.S.R.* should be referred to throughout
as it is essential that the pupils should be thoroughly conversant
with the range and power of weapons; in fact these details cannot
be referred to too often.

4. It is not sufficient to merely teach and explain the principles
of *F.S.R.* and *Field Engineering* in words only. It is essential that
the pupils' appreciation of the teaching should be frequently tested
by working out short and very simple schemes, so as to enable the
instructor to correct any false impressions that have been acquired
before they are too firmly fixed.

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Erratum. *R.E.* 7, September, 1925, page 474. The last date of Loos was **8th** October.

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BATTLE HONOURS OF ROYAL ENGINEER UNITS.

(Continued.)

MOUNT SORREL. 2nd—15th JUNE, 1916.

Unit.	Formation.	E.	Remarks.
177th Tunnelling Co.	2nd Army	E.	
182nd Tunnelling Co.	,,	N.E.	
250th Tunnelling Co.	,,	,,	
1st Canadian Tunnelling Co.	,,	E.	
2nd Canadian Tunnelling Co.	,,	,,	
3rd Canadian Tunnelling Co.	,,	,,	
217th A.T. Co.	,,	N.E.	
213th A.T. Co.	,,	,,	
1st Canadian A.T. Co.	,,	,,	
2nd Canadian A.T. Co.	,,	,,	
3rd Canadian A.T. Co.	,,	,,	
Corps Signals	XIVth Corps	,,	
1st Siege Co. R. Monmouth R.E.	,,	,,	
Corps Signals	Canadian Corps	D.	
83rd Fld. Co.	20th Div.	E.	
84th Fld. Co.	,,	N.E.	
96th Fld. Co.	,,	,,	
20th Div. Sig. Co.	,,	,,	
1st Canadian Fld. Co.	1st Canadian Div.	E.	
2nd Canadian Fld. Co.	,,	,,	
3rd Canadian Fld. Co.	,,	,,	
1st Canadian Div. Sig. Co.	,,	,,	
4th Canadian Fld. Co.	2nd Canadian Div.	,,	
5th Canadian Fld. Co.	,,	,,	
6th Canadian Fld. Co.	,,	,,	
2nd Canadian Div. Sig. Co.	,,	,,	
7th Canadian Fld. Co.	3rd Canadian Div.	,,	
8th Canadian Fld. Co.	,,	,,	
9th Canadian Fld. Co.	,,	,,	
3rd Canadian Div. Sig. Co.	,,	,,	

ALBERT 1916. 1st—13th July.

Unit.	Formation	E.	Remarks.
133 A.T. Co.	4th Army	E.	
134 ,,	,,	,,	No unit diary. Verified by diary of C.R.E. 7th Divn.
135 ,,	,,	,,	
142 ,,	,,	N.E.	
148 ,,	,,	E.	
149 ,,	,,	,,	
214 ,,	,,	,,	
238 ,,	,,	,,	
280 ,,	,,	,,	

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ALBERT 1916. 1st—13th JULY.

Unit.	Formation.	E.	Remarks.
281 A.T. Co.	4th Army	E.	
282 ,,	,,	,,	
221 ,,	,,	,,	
232 ,,	,,	D.	No unit diary. Mentioned in diary of C.E. XIII Corps.
236 ,,	,,	E.	No unit diary. Verified by diary of C.E. X Corps.
216 ,,	,,	D.	No unit diary. No mention in other diaries.
1/1st Hants. A.T. Co.	,,	,,	No unit diary. No mention in other diaries.
174 Tunnelling Co.	,,	E.	
179 ,,	,,	,,	
183 ,,	,,	,,	
252 ,,	,,	,,	
178 ,,	5th Army	,,	
4th Pontoon Park	4th Army	,,	
5th ,,	,,	,,	
No. 2 Siege Co. R. Anglesey	,,	,,	
29th Advanced Park Co.	G.H.Q.	N.E.	
No. 1 A.A. Searchlight Section	,,	,,	
No. 2 A.A. Searchlight Section	,,	,,	
1st Bn. Special Brigade	,,	D.	Part of diary missing.
2nd ,,	,,	E.	
5th ,,	,,	,,	
110th Railway Co.	,,	,,	
IIIrd Corps Signal Co.	IIIrd Corps	,,	
VIII ,,	VIII ,,	,,	
X ,,	X ,,	,,	
XIII ,,	XIII ,,	,,	
XV ,,	XV ,,	,,	
23rd Fd. Co.	1st Divn.	,,	
26th ,,	,,	,,	
1/1st Lowland Fd. Co.	,,	,,	
1st Divl. Sig. Co.	,,	,,	
2nd Fd. Co.	8th Divn.	,,	
15th Fd. Co.	,,	,,	
1/1st Home Counties Fd. Co.	,,	,,	
8th Divl. Sig. Co.	,,	,,	
69th Fd. Co.	12th Divn.	,,	
70th Fd. Co.	,,	,,	
87th Fd. Co.	,,	,,	
12th Divl. Sig. Co.	,,	,,	
81st Fd. Co.	19th Divn.	,,	
82nd Fd. Co.	,,	,,	
94th Fd. Co.	,,	,,	
19th Divl. Sig. Co.	,,	,,	
101st Fd. Co.	23rd Divn.	,,	
102nd Fd. Co.	,,	,,	
128th Fd. Co.	,,	,,	
23rd Divl. Sig. Co.	,,	,,	
207th Fd. Co.	34th Divn.	,,	
208th Fd. Co.	,,	,,	
209th Fd. Co.	,,	,,	
34th Divl. Sig. Co.	,,	,,	
9th Fd. Co.	4th Divn.	,,	
1/1st Durham Fd. Co.	,,	,,	
1/1st Renfrew Fd. Co.	,,	,,	
4th Divl. Sig. Co.	,,	,,	

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ALBERT 1916. 1st—13th JULY.

Unit.	Formation.	E.	Remarks.
1/3rd Kent. Fd. Co.	29th Divn.	E.	
1/2nd London Fd. Co.	,,	,,	
1/1st W. Riding Fd. Co.	,,	,,	
29th Divl. Sig. Co. (1/1st London Divl. Sig. Co.).	,,	,,	
210th Fd. Co.	31st Divn.	,,	
211th Fd. Co.	,,	,,	
233rd Fd. Co.	,,	,,	
31st Divl. Sig. Co.	,,	,,	
1/1st S. Midland Fd. Co.	48th Divn.	,,	
2/1st S. Midland Fd. Co.	,,	,,	
1/2nd S. Midland Fd. Co.	,,	,,	
48th Divl. Sig. Co.	,,	,,	
105th Fd. Co.	25th Divn.	,,	
106th Fd. Co.	,,	,,	
130th Fd. Co.	,,	,,	
25th Div. Sig. Co.	,,	,,	
206th Fd. Co.	32nd Divn.	,,	
218th Fd. Co.	,,	,,	
219th Fd. Co.	,,	,,	
32nd Divl. Sig. Co.	,,	,,	
121st Fd. Co.	36th Divn.	,,	
122nd Fd. Co.	,,	,,	
150th Fd. Co.	,,	,,	
36th Divl. Sig. Co.	,,	,,	
57th Fd. Co.	49th Divn.	,,	
1/2nd W. Riding Fd. Co.	,,	,,	
2/1st W. Riding Fd. Co.	,,	,,	
49th Divl. Sig. Co.	,,	,,	
56th Fd. Co.	3rd Divn.	,,	
1/1st Cheshire Fd. Co.	,,	,,	
1/1st E. Riding Fd. Co.	,,	,,	
3rd Divl. Sig. Co.	,,	,,	
63rd Fd. Co.	9th Divn.	,,	
64th Fd. Co.	,,	,,	
90th Fd. Co.	,,	,,	
9th Divl. Sig. Co.	,,	,,	
79th Fd Co.	18th Divn.	,,	
80th Fd. Co.	,,	,,	
92nd Fd. Co.	,,	,,	
18th Divl. Sig. Co.	,,	,,	
200th Fd. Co.	30th Divn.	,,	
201st Fd. Co.	,,	,,	
202nd Fd. Co.	,,	,,	
30th Divl. Sig. Co.	,,	,,	
203rd Fd. Co.	35th Divn.	,,	
204th Fd. Co.	,,	,,	
205th Fd. Co.	,,	,,	
35th Divl. Sig. Co.	,,	,,	
1/1st Edinburgh Fd. Co.	56th Divn.	,,	
2/1st London Fd. Co.	,,	,,	
2/2nd London Fd. Co.	,,	,,	
56th Divl. Sig. Co.	,,	,,	
54th Fd. Co.	7th Divn.	,,	
95th Fd. Co.	,,	,,	
1/3rd Durham Fd. Co.	,,	,,	
7th Divl. Sig. Co.	,,	,,	

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ALBERT 1916. 1st—13st JULY.

Unit.	Formation.	E.	Remarks.
77th Fd. Co.	17th Divn.	E.	
78th Fd. Co.	,,	,,	
93rd Fd. Co.	,,	,,	
17th Divl. Sig. Co.	,,	,,	
97th Fd. Co.	21st Divn.	,,	
98th Fd. Co.	,,	,,	
126th Fd. Co.	,,	,,	
21st Divl. Sig. Co.	,,	,,	
11th Fd. Co.	33rd Divn.	N.E.	
212th Fd. Co.	,,	,,	
222nd Fd. Co.	,,	E.	
33rd Divl. Sig. Co.	,,	N.E.	
123rd Fd. Co.	38th Divn.	E.	
124th Fd. Co.	,,	,,	
151st Fd. Co.	,,	,,	
38th Divl. Sig. Co.	,,	,,	
6th Labour Bn.	G.H.Q.	,,	
B. Co. 2nd Labour Bn.	,,	,,	No diary. Verified by diary of C.E. XV Corps.
D. Co. 2nd Labour Bn.	,,	,,	
D. Co. 12th Labour	,,	D.	No diary. Mentioned by C.E. XV Corps. (These Labour Bns. are not mentioned in Orders of battle and any verification is difficult. Very few unit diaries appear to have been kept.)
3rd Fd. Squadron	Cav. Divn.	,,	No unit diary. Definitely mentioned by C.E. XVIII Corps as working in area on 13.7.16.

BAZENTIN 14th—17th JULY, 1916.

Unit.	Formation.	E.	Remarks.
133 A.T. Co.	4th Army	E.	
134 ,,	,,	,,	
135 ,,	,,	,,	
142 ,,	,,	,,	
148 ,,	,,	,,	
149 ,,	,,	D.	Very brief diary.
214 ,,	,,	E.	
216 ,,	,,	D.	No unit diary. No mention in other diaries.
221 ,,	,,	E.	
232 ,,	,,	D.	No unit diary. C.E. X Corps mentions move out of area 12.7.16.
236 ,,	,,	E.	No diary. Verified by diary of C.E. X Corps.
238 ,,	,,	,,	
280 ,,	,,	N.E.	
281 ,,	,,	E.	
282 ,,	,,	,,	
1/1st Hants A.T. Co.	,,	D.	No unit diary. No mention in other diaries.
132 A.T. Co.	3rd Army	N.E.	
174 Tunnelling Co.	4th Army	E.	
179 ,,	,,	,,	
183 ,,	,,	,,	
252 ,,	,,	N.E.	
178 ,,	5th Army	E.	

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BAZENTIN 14th—17th JULY, 1916.

Unit.	Formation.	E.	Remarks.
1 Pontoon Park	4th Army	E.	
1 ,,	,,	,,	
d Siege Co. R. Anglesey	,,	N.E.	
). 1 Bn. Special Brigade	G.H.Q.	,,	
). 2 Bn. Special Brigade	,,	D.	
). 5 Bn. Special Brigade	,,	E.	
9th Railway Co.	,,	,,	
1 Labour Bn.	,,	N.E.	No other division or mention of Labour Bns.
Co. 2nd Labour Bn.	,,	D.	
A. Corps Signal Co.	II A.C.	N.E.	
[,,	III ,,	,,	
,,	IV ,,	,,	
,,	X ,,	,,	
III ,,	XIII ,,	,,	
V ,,	XV ,,	,,	
d Indian Fd. Sqn.	2nd Indian Cav. Divn.	E.	
d Indian Sig. Sqn.	,,	,,	
rd Fd. Co.	1st Divn.	,,	
th Fd. Co.	,,	,,	
1st Lowland Fd. Co.	,,	,,	
t Divn. Sig. Co.	,,	,,	
1st Fd. Co.	23rd Divn.	N.E.	
2nd Fd. Co.	,,	,,	
8th Fd. Co.	,,	,,	
rd Divl. Sig. Co.	,,	,,	
7th Fd. Co.	34th Divn.	E.	
8th Fd. Co.	,,	,,	
9th Fd. Co.	,,	,,	
th Divl. Sig. Co.	,,	,,	
th Fd. Co.	3rd Divn.	,,	
1st Cheshire Fd. Co.	,,	,,	
1st E. Riding Fd. Co.	,,	,,	
d Divl. Sig. Co.	,,	,,	
rd Fd. Co.	9th Divn.	,,	
th Fd. Co.	,,	,,	
th Fd. Co.	,,	,,	
h Divl. Sig. Co.	,,	,,	
th Fd. Co.	18th Divn.	,,	
th Fd. Co.	,,	,,	
nd Fd. Co.	,,	,,	
th Divl. Sig. Co.	,,	,,	
th Fd. Co.	7th Divn.	,,	
th Fd. Co.	,,	,,	
3rd Durham Fd. Co.	,,	,,	
h Divl. Sig. Co.	,,	,,	
th Fd. Co.	21st Divn.	,,	
th Fd. Co.	,,	,,	
6th Fd. Co.	,,	,,	
st Divl. Sig. Co.	,,	,,	
th Fd. Co.	33rd Divn.	,,	
2th Fd. Co.	,,	,,	
2nd Fd. Co.	,,	,,	
rd Divl. Sig. Co.	,,	,,	
5th Fd. Co.	25th Divn.	,,	
6th Fd. Co.	,,	,,	
0th Fd. Co.	,,	,,	
th Divl. Sig. Co.	,,	,,	
6th Fd. Co.	32nd Divn.	,,	

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BAZENTIN 14th—17th JULY, 1916.

Unit.	Formation.	E.	Remarks.
218th Fd. Co.	32nd Divn.	E.	
219th Fd. Co.	,,	,,	
32nd Divl. Sig. Co.	,,	,,	
1/1st South Midland Fd. Co.	48th Divn.	N.E.	
1/2nd South Midland Fd. Co.	,,	E.	
2/1st South Midland Fd. Co.	,,	,,	
48th Divl. Sig. Co.	,,	,,	
57th Fd. Co.	49th Divn.	,,	
1/2nd W. Riding Fd. Co.	,,	,,	
2/1st W. Riding Fd. Co.	,,	N.E.	
49th Divl Sig. Co.	,,	E.	
203rd Fd. Co.	35th Divn.	N.E.	
204th Fd. Co.	,,	E.	
205th Fd. Co.	,,	,,	
35th Divl. Sig. Co.	,,	N.E.	

DELVILLE WOOD. 15th JULY—3rd SEPTEMBER, 1916.

Unit.	Formation	E.	Remarks.
5th Fd. Co.	2nd Divn.	E.	
226th Fd. Co.	,,	,,	
1/1st E. Anglian Fd. Co.	,,	,,	
2nd Divl. Sig. Co.	,,	N.E.	
56th F.D. Co.	3rd Divn.	E.	
1/1st Cheshire Fd. Co.	,,	D.	
1/1st E. Riding Fd. Co.	,,	D.	Diary for July missing.
3rd Divl. Sig. Co.	,,	N.E.	
63rd Fd. Co.	9th Divn.	E.	
64th Fd. Co.	,,	,,	
90th Fd. Co.	,,	,,	
9th Divl. Sig. Co.	,,	N.E.	
All R.E. Units of 18th Divn.	18th Divn.	,,	
103rd Fd. Co.	24th Divn.	E.	
104th Fd. Co.	,,	,,	
129th Fd. Co.	,,	,,	
24th Divl. Sig. Co.	,,	N.E.	
83rd Fd. Co.	20th Divn.	N.E.	
84th Fd. Co.	,,	D.	
96th Fd. Co.	,,	N.E.	
20th Divl. Sig. Co.	,,	E.	
54th Fd. Co.	7th Divn.	D.	
95th Fd. Co.	,,	,,	
1/3rd Durham Fd. Co.	,,	E.	
7th Divl. Sig. Co.	,,	N.E.	
1st New Zealand Fd. Co.	N.Z. Divn.	E.	
2nd New Zealand Fd. Co.	,,	,,	
3rd New Zealand Fd. Co.	,,	D.	
179 Tunnelling Co.	4th Army	E.	
2nd Indian Fd. Sqdn.	2nd Indian Cav. Divn.	,,	
59th Fd. Co.	5th Divn.	,,	
1/2nd Home Counties Fd. Co.	,,	D.	
1/2nd Durham Fd. Co.	,,	E.	
5th Divl. Sig. Co.	,,	N.E.	

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POZIERES. 23rd JULY—3rd SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
133 A.T. Co.	4th Army	N.E.	
134 ,,	,,	D.	No unit diary. No mention in C.E.'s diary.
135 ,,	,,	E.	
142 ,,	,,	N.E.	
148 ,,	,,	E.	
149 ,,	,,	D.	Very brief diary.
214 ,,	,,	E.	
216 ,,	,,	D.	No unit diary. No mention in C.E's. diary.
217 ,,	,,	N.E.	
221 ,,	,,	E.	
232 ,,	,,	D.	No unit diary. No mention in C.E's. diary.
236 ,,	,,	E.	No unit diary. Verified by diary of C.E. II Corps.
238 ,,	,,	N.E.	
280 ,,	,,	E.	
281 ,,	,,	,,	
282 ,,	,,	,,	
1/1st Wilts. A.T. Co.	,,	N.E.	
1/3rd Cornwall A.T. Co.	,,	E.	No unit diary. Verified by diary of C.E. IV Corps.
1st Canadian A.T. Co.	,,	,,	
1/1st Hants A.T. Co.	,,	N.E.	
174 Tunnelling Co.	,,	,,	
178 ,,	,,	E.	
179 ,,	,,	,,	
181 ,,	,,	,,	
183 ,,	,,	N.E.	
252 ,,	,,	,,	
No. 2 Siege Co. R. Anglesey	,,	,,	
No. 1 Siege Co. R. Monmouth	,,	E.	
No. 4 Pontoon Park	,,	,,	
No. 5 Pontoon Park	,,	,,	
No. 2 Labour Bn.	,,	D.	Detachments of these units were in Area.
No. 6 Labour Bn.	,,	,,	
III Corps Sig. Co.	III Corps	E.	
II ,,	II Corps	,,	
1st Anzac Corps Sig. Co.	1st Anzac Corps	,,	
No. 2 Bn. Special Brigade	G.H.Q.	,,	
No. 5 Bn. Special Brigade	,,	,,	
3rd Fd. Squadron	3rd Cav. Divn.	,,	
2nd Indian Fd. Squadron	2nd Indian Cav. Divn.	,,	
23rd Fd. Co.	1st Divn.	,,	
26th Fd. Co.	,,	,,	
1/1st Lowland Fd. Co.	,,	,,	
1st Divl. Sig. Co.	,,	,,	
73rd Fd. Co.	15th Divn.	,,	
74th Fd. Co.	,,	,,	
91st Fd. Co.	,,	,,	
15th Divl. Sig. Co.	,,	,,	
81st Fd. Co.	19th Divn.	,,	
82nd Fd. Co.	,,	,,	
94th Fd. Co.	,,	,,	
19th Divl. Sig. Co.	,,	,,	
101st Fd. Co.	23rd Divn.	,,	
102nd Fd. Co.	,,	,,	
128th Fd. Co.	,,	,,	

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POZIERES. 23rd JULY—3rd SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
23rd Divl. Sig. Co.	23rd Divn.	E.	
207th Fd. Co.	34th Divn.	,,	
208th Fd. Co.	,,	,,	
209th Fd. Co.	,,	,,	
34th Divl. Sig. Co.	,,	,,	
69th Fd. Co.	12th Divn.	,,	
70th Fd. Co.	,,	,,	
87th Fd. Co.	,,	,,	
12th Divl. Sig. Co.	,,	,,	
105th Fd. Co.	25th Divn.	,,	
106th Fd. Co.	,,	,,	
130th Fd. Co.	,,	,,	
25th Divl. Sig. Co.	,,	,,	
1/1st S. Midland Fd. Co.	48th Divn.	,,	
1/2nd S. Midland Fd. Co.	,,	,,	
2/1st S. Midland Fd. Co.	,,	,,	
48th Divl. Sig. Co.	,,	,,	
57th Fd. Co.	49th Divn.	,,	
1/2nd West Riding Fd. Co.	,,	,,	
2/1st West Riding Fd. Co.	,,	,,	
49th Divl. Sig. Co.	,,	,,	
1st Australian Fd. Co.	1st Aus. Divn.	,,	
2nd Australian Fd. Co.	,,	,,	
3rd Australian Fd. Co.	,,	,,	
1st Aus. Divl. Sig. Co.	,,	,,	
5th Aus. Fd. Co.	2nd Aus. Divn.	,,	
6th Aus. Fd. Co.	,,	,,	
7th Aus. Fd. Co.	,,	,,	
2nd Aus. Divl. Sig. Co.	,,	,,	
4th Aus. Fd. Co.	4th Aus. Divn.	,,	
12th Aus. Fd. Co.	,,	,,	
13th Aus. Fd. Co.	,,	,,	
4th Aus. Divl. Sig. Co.	,,	,,	
7th Divl. Sig. Co.	7th Divn.	,,	
54th Fd. Co.	,,	,,	
95th Fd. Co.	,,	,,	
1/3rd Durham Fd. Co.	,,	,,	
1st Canadian Fd. Co.	1st Can. Divn.	,,	
2nd Canadian Fd. Co.	,,	,,	
3rd Canadian Fd. Co.	,,	,,	
1st Can. Divl. Sig. Co.	,,	N.E.	
59th Fd. Co.	5th Divn.	,,	
1/2nd Home Counties Fd. Co.	,,	E.	
1/2nd Durham Fd. Co.	,,	,,	
5th Divl. Sig. Co.	,,	,,	
1/3rd London Fd. Co.	47th Divn.	N.E.	
2/3rd London Fd. Co.	,,	E.	
1/4th London Fd. Co.	,,	,,	
47th Divl. Sig. Co.	,,	N.E.	
7th Fd. Co.	50th Divn.	E.	
1/1st Northumbrian Fd. Co.	,,	,,	
2/2nd Northumbrian Fld. Co.	,,	D.	
50th Div. Sig. Co.	,,	N.E.	

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GUILLEMONT. 3rd—6th SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
280 A.T. Co.	4th Army	E.	No other A.T. Cos. of 4th Army can be identified in Area.
178 Tunnelling Co.	,,	D.	No other Tunnelling Cos. of 4th Army can be identified in Area.
183 ,,	,,	E.	
1st Fd. Squadron	1st Cav. Div.	N.E.	
2nd Indian Fld. Squadron	2nd Ind. Cav. Div.	E.	
No. 2 Bn. Special Bde. R.E.	G.H.Q.	,,	No other Bn. of special Bde. can be identified in Area.
59th Fd. Co.	5th Div.	,,	
1/2nd Home Counties Fd. Co.	,,	,,	
1/2nd Durham Fd. Co.	,,	,,	
5th Div. Sig. Co.	,,	,,	
155th Fd. Co.	16th Div.	,,	
156th Fd. Co.	,,	,,	
157th Fd. Co.	,,	,,	
16th Div. Sig. Co.	,,	,,	
83rd Fd. Co.	20th Div.	,,	
84th Fd. Co.	,,	,,	
96th Fd. Co.	,,	,,	
20th Div. Sig. Co.	,,	,,	
54th Fd. Co.	7th Div.	,,	
95th Fd. Co.	,,	,,	
1/3rd Durham Fd. Co.	,,	,,	
7th Div. Sig. Co.	,,	,,	
103rd Fd. Co.	24th Div.	,,	
104th Fd. Co.	,,	,,	
129th Fd. Co.	,,	,,	
24th Div. Sig. Co.	,,	N.E.	
1/1st W. Lancs. Fd. Co.	5th Div.	E.	
2/1st W. Lancs. Fd. Co.	,,	,,	
2/2nd W. Lancs. Fd. Co.	,,	N.E.	
55th Div. Sig. Co.	,,	D.	
1/1st Edinburgh Fd. Co.	56th Div.	N.E.	
2/1st London Fd. Co.	,,	E.	
2/2nd London Fd. Co.	,,	N.E.	
56th Div. Sig. Co.	,,	N.E.	
1st New Zealand Fd. Co.	N.Z. Div.	E.	
2nd New Zealand Fd. Co.	,,	,,	
3rd New Zealand Fd. Co.	,,	,,	
N.Z Div. Sig. Co.	,,	N.E.	
228th Fd. Co.	41st Div.	E.	
233rd Fd. Co.	,,	,,	
237th Fd. Co.	,,	,,	
41st Div. Sig. Co.	,,	N.E.	

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GINCHY. 9th SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
280 A.T. Co.	4th Army	E.	No other A.T. Co's. of 4th Army can be identified in Area.
178 Tunnelling Co.	,,	D.	No other Tunnelling Co. of
183 ,,	,,	E.	4th Army can be identified in Area.
1st Field Squadron	1st Cav. Divn.	,,	
2nd Indian Field Squadron	2nd Ind. Cav. Divn.	,,	
No. 2 Bn. Special Brigade	G.H.Q.	N.E.	No other Bn. of Special Bde. can be located in area.
155th Fd. Co.	16th Divn.	E.	
156th Fd. Co.	,,	,,	
157th Fd. Co.	,,	,,	
16th Divl. Sig. Co.	,,	,,	
1/1st Edinburgh Fd. Co.	56th Divn.	,,	
2/1st London Fd. Co.	,,	N.E.	
2/2nd London Fd. Co.	,,	E.	
56th Divl. Sig. Co.	,,	,,	
1/1st W. Lancs. Fd. Co.	55th Divn.	N.E.	
2/1st W. Lancs. Fd. Co.	,,	E.	
2/2nd W. Lancs. Fd. Co.	,,	N.E.	
55th Divl. Sig. Co.	,,	D.	
54th Fd. Co.	7th Divn.	E.	
95th Fd. Co.	,,	,,	
1/3rd Durham Fd. Co.	,,	,,	
7th Divl. Sig. Co.	,,	N.E.	
103rd Fd. Co.	24th Divn.	E.	
104th Fd. Co.	,,	,,	
129th Fd. Co.	,,	,,	
24th Divl. Sig. Co.	,,	N.E.	
1st New Zealand Fd. Co.	N.Z. Divn.	E.	
2nd New Zealand Fd. Co.	,,	,,	
3rd New Zealand Fd. Co.	,,	,,	
N.Z. Divl. Sig. Co.	,,	N.E.	
228th Fd. Co.	41st Divn.	E.	
233rd Fd. Co.	,,	,,	
237th Fd. Co.	,,	,,	
41st Divl. Sig. Co.	,,	N.E.	

FLERS-COURCELETTE. 15TH—22ND SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
133rd A.T. Co.	4th Army	E.	
134th ,,	,,	,,	Verified from diary of C.E. XVth Corps.
142nd ,,	,,	D.	
149th ,,	,,	,,	No unit diary.
214th ,,	,,	N.E.	
216th ,,	,,	D.	No unit diary.
217th ,,	,,	E.	
221st ,,	,,	D.	
232nd ,,	,,	,,	No unit diary.
238th ,,	,,	N.E.	
280th ,,	,,	E.	
281st ,,	,,	,,	
282nd ,,	,,	N.E.	

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FLERS-COURCELETTE. 15th—22nd SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
1/3rd Cornwall A.T. Co.	4th Army	D.	No unit diary.
1/1st Wilts. A.T. Co.	"	E.	
178 Tunnelling Co.	"	"	
179 "	"	"	
183 "	"	"	
4th Pontoon Park	"	"	
5th "	"	N.E.	
No. 2 Labour Bn.	"	E.	
135th A.T. Co.	Res. Army	"	
148th A.T. Co.	"	"	
236th A.T. Co.	"	D.	No unit diary.
1/1st Hants. A.T. Co.	"	N.E.	
No. 2 Siege Co. R. Anglesey R.E.	"	"	
No. 1 Siege Co. R. Monmouth R.E.	"	E.	
7th Canadian A.T. Co.	"	N.E.	
174 Training Co.	"	"	
252 "	"	"	
No. 6 Labour Bn.	"	"	
IInd Corps. Sig. Co.	IInd Corps	E.	
IIIrd Corps Sig. Co.	IIIrd Corps	"	
XIVth Corps. Sig. Co.	XIVth Corps	"	No unit diary. Presumptive evidence.
XVth Corps Sig. Co.	XVth Corps	"	
Can. A.C. Sig. Co.	Can. Corps	"	
No. 1 Special Co. Special Brigade	G.H.Q.	"	
110th Railway Co.	"	D.	
119th "	"	E.	
23rd Fd. Co.	1st Div.	"	
26th Fd. Co.	"	"	
1/1st Lowland Fd. Co.	"	"	
1st Div. Sig. Co.	"	"	
73rd Fd. Co.	15th Div.	"	
74th Fd. Co.	"	"	
91st Fd. Co.	"	"	
15th Div. Sig. Co.	"	"	
101st Fd. Co.	23rd Div.	"	
102nd Fd. Co.	"	"	
128th Fd. Co.	"	"	
23rd Div. Sig. Co.	"	"	
1/3rd London Fd. Co.	47th Div.	"	
1/4th "	"	"	
2/3rd "	"	"	
47th Div. Sig. Co.	"	"	
7th Fd. Co.	50th Div.	"	
1/1st Northumbrian Fd. Co.	"	"	
1/2nd Northumbrian Fd. Co.	"	"	
50th Div. Sig. Co.	"	"	
55th Fd. Co.	Guards Div.	"	
75th Fd. Co.	"	"	
76th Fd. Co.	"	"	
Guards Div. Sig. Co.	"	"	
59th Fd. Co.	5th Div.	"	
1/2nd Durham Fd. Co.	"	"	
1/2nd Home Counties Fd. Co.	"	"	
5th Div. Sig. Co.	"	"	
12th Fd. Co.	6th Div.	"	
1/1st London Fd. Co.	"	"	

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FLERS-COURCELETTE. 15th—22nd SEPTEMBER, 1916.

Unit.	Formation.	E.	Remarks.
2/2nd West Riding Fd. Co.	6th Div.	E.	
6th Div. Sig. Co.	,,	,,	
83rd Fd. Co.	20th Div.	,,	
84th Fd. Co.	,,	,,	
96th Fd. Co.	,,	,,	
20th Div. Sig. Co.	,,	,,	
1/1st Edinburgh Fd. Co.	56th Div.	,,	
2/1st London Fd. Co.	,,	,,	
2/2nd ,,	,,	,,	
56th Div. Sig. Co.	,,	,,	
61st Fd. Co.	14th Div.	,,	
62nd Fd. Co.	,,	,,	
89th Fd. Co.	,,	,,	
14th Div. Sig. Co.	,,	,,	
97th Fd. Co.	21st Div.	,,	
98th Fd. Co.	,,	,,	
126th Fd. Co.	,,	,,	
21st Div. Sig. Co.	,,	,,	
228th Fd. Co.	41st Div.	,,	
223rd Fd. Co.	,,	,,	
237th Fd. Co.	,,	,,	
41st Div. Sig. Co.	,,	,,	
1/1st West Lancs. Fd. Co.	55th Div.	,,	
2/1st West Lancs. Fd. Co.	,,	,,	
2/2nd West Lancs. Fd. Co.	,,	,,	
55th Div. Sig. Co.	,,	,,	
1st New Zealand Fd. Co.	N.Z. Div.	,,	
2nd New Zealand Fd. Co.	,,	,,	
3rd New Zealand Fd. Co.	,,	,,	
N.Z. Div Sig. Co.	,,	,,	
67th Fd. Co.	11th Div.	,,	
68th Fd. Co.	,,	,,	
86th Fd. Co.	,,	,,	
11th Div. Sig. Co.	,,	,,	
57th Fd. Co.	49th Div.	,,	
1/2nd West Riding Fd. Co.	,,	,,	
2/1st West Riding Fd. Co.	,,	,,	
49th Div. Sig. Co.	,,	,,	
1st Can. Fd. Co.	1st Can. Div.	D.	
2nd ,,	,,	E.	
3rd ,,	,,	D.	
1st Can. Div. Sig. Co.	,,	E.	
4th Can. Fd. Co.	2nd Can. Div.	,,	
5th ,,	,,	,,	
6th ,,	,,	,,	
2nd Can. Div. Sig. Co.	,,	,,	
7th Can. Fd. Co.	3rd Can. Div.	,,	
8th ,,	,,	N.E.	
9th ,,	,,	,,	
3rd Can. Div. Sig. Co.	,,	E.	
1st Field Squadron	1st Cav. Div.	,,	
1st Signal Squadron	,,	,,	
1st Ind. Fd. Squadron	1st Ind. Cav. Div.	,,	
2nd ,,	2nd Ind Cav. Div.	,,	
2nd Ind. Sig. Squad.	,,	,,	

To be Continued.

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MODERN PRACTICE IN E. AND M. ENGINEERING.

I. EARTHING THE NEUTRAL POINT IN H.T. 3-PHASE A.C. SYSTEMS.

By LIEUT. W. M. N. MORECOMBE, B.Sc. (Eng.) R.E. (Co. Bn.).

THE practice of earthing the neutral point in H.T., A.C. systems is now well established in this country, and it is understood that the forthcoming revised issue of the " E.C. Regulations for Securing the Safety of the Public " will contain a clause making N.P. earthing compulsory.

The matter is dealt with in the *Military Manual of Electrical Engineering*, pp. 76 to 79, but the object of the present article is to explain the considerations involved a little more fully, particularly with regard to H.T. systems,

I. ELEMENTARY CONSIDERATIONS.

(*a*) *Neutral Point Insulated.*

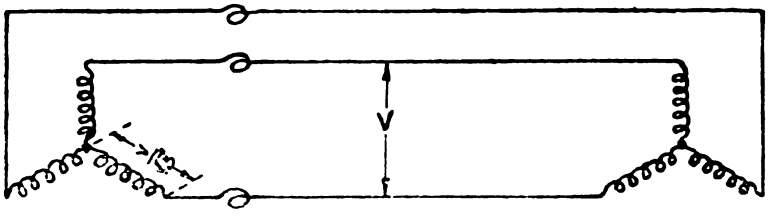

FIG. 1.

Consider first a star-connected alternator feeding a three-wire H.T. line at pressure V. (Fig. 1). The insulation of each line has normally to withstand a pressure $\frac{V.}{\sqrt{3}}$

It might be thought at first sight that it has to withstand a pressure $\frac{V}{2}$ only, but, assuming a pure sine E.M.F. wave and perfect line insulation, the N.P. is maintained at earth (*i.e.*, zero) potential by the star-connected condensers formed by the line capacity.

Unfortunately, a pure sine wave is never actually attained (although closely approached by modern alternators) and triple harmonic E.M.F.s (and multiples thereof), being co-phasal with regard to the three-line wires, are effective between the N.P. and earth, although they do not appear in the voltage between line and N.P.

So, in practice, an insulated N.P. will generally be above earth potential, due to the triple harmonic E.M.F.s, and the pressure

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between each line and earth will be somewhat greater than $\frac{V}{\sqrt{3}}$

Now, since perfect line insulation is never attained, especially with overhead lines, the zero point of the system may be anywhere on the generator windings, depending upon the relative values of the individual insulation resistances of the three lines. Consequently the *potential of the N.P. is not stable.* In the limit, if an earth fault of low resistance occurs on one line conductor, the zero point of the system is shifted to that conductor, and the P.D. to earth of the other two conductors is raised from $\frac{V}{\sqrt{3}}$ to V.

Therefore the *insulation must be designed for a working voltage of V volts.*

Now, with regard to isolation of faults, if simple over-load protection is installed, an earth fault on one line only will not cause an interruption of supply. An earth must develop on a second line, thus producing a short circuit sufficiently low in resistance to operate the O.L. trips, which will require at least 150 to 200 per cent. of full load current to function, depending on the setting. This is most objectionable, as will be emphasised later.

(b) Neutral Point Earthed at Generating Station.

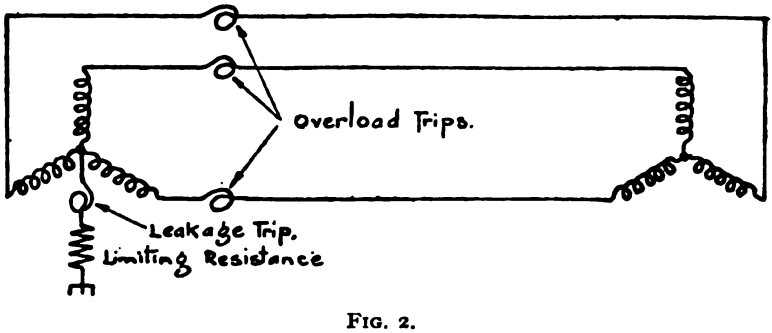

FIG. 2.

If the N.P. of the alternator is earthed, its potential is definitely zero, and the P.D. between each line conductor and earth is now limited to $\frac{V}{\sqrt{3}}$ (or a little higher, due to harmonics).

There could, therefore, be some saving in line insulation with this arrangement, but in actual practice, except in the case of very high pressures, machinery and lines are designed for full line pressure V, and advantage taken of the larger factor of safety.

An earth on one line will now cause an interruption of supply by operating the O.L. trip in that line. But this arrangement is still open to the objection that large currents may have to be broken, and to overcome this difficulty it is usual to insert a resistance

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in the earth connection to limit the maximum possible leakage current to that necessary to operate the O.L. trips (see Fig. 2).

If, however, a trip coil is inserted in the neutral connection to earth, it will not be affected by normal overload currents, and may, therefore, be designed to trip with a relatively small leakage current, and the circuit can be isolated with smaller shock to the system.

(c) *Connection with Earth at more than one Point.*

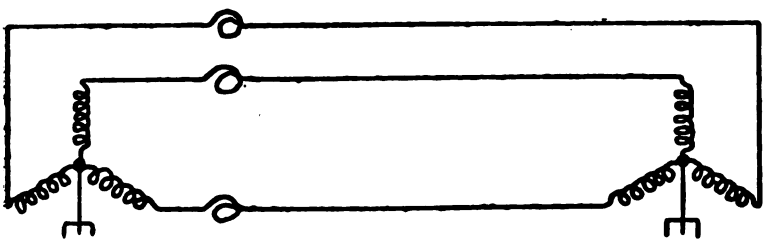

FIG. 3.

In the two cases considered above, when the insulation of all the lines is perfect, the only earth currents are those due to capacity, and these will be comparatively small in amount. But if connection with earth is made at two points, say, at the N.P. of alternator and also at the N.P. of a motor at the receiving end of a line (Fig. 3), a definite conducting path is provided through the earth.

With sine E.M.F. waves the two neutral points will be at the same potential unless the load is unbalanced, but, as mentioned above, the triple harmonic E.M.F.s are co-phasal with regard to the three line conductors, and, therefore, a single phase triple harmonic current will circulate through the three line conductors in parallel and back from one earth connection to the other. As far as the power system itself is concerned these effects are seldom of sufficient magnitude to cause inconvenience, but the arrangement produces a maximum of inductive effect on telephone circuits and is very undesirable.

II. THE EFFECTS OF EARTHING THE N.P. ON THE GENERAL WORKING OF THE POWER SYSTEM CAN NOW BE CONVENIENTLY CONSIDERED UNDER THREE HEADS, VIZ :—

(1) Safety from shock and fire.

(2) Continuity of supply.

(3) Telephone Interference.

(1) *Safety from Shock and Fire.*

It is sometimes argued that there is less danger from shock to anyone coming in contact with one conductor of a H.T. system if the N.P. is insulated.

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This may be true (theoretically) in very small systems with only, say, two or three miles of line, but it is absolutely foolish to rely on this possibility.

In general, as explained above, the effect of capacity is to keep the N.P. at earth potential, and a person making contact between one conductor and earth through his body receives practically the same shock as if the N.P. of the system were permanently earthed. (The considerations affecting L.T. systems are quite different. Earthing the N.P. secures economy in copper without increasing danger from shock).

In the case of overhead lines it is obviously essential to cut off the line if a conductor falls to the ground, and the E.C. Regulations for O.H. lines make it compulsory to instal apparatus to render a line conductor "dead" if it falls. *This Regulation implies working with N.P. earthed* to enable leakage protection to be installed.

With regard to fire, since in systems of moderate size, the capacity current flowing through an earth fault and the heat generated thereby may be considerable when the N.P. is insulated, risk of fire is introduced, and if the leak is through combustible material, as in machines and cables, it will probably develop into a short-circuit between phases. Moreover, in gassy atmospheres, *e.g.*, mines, risk of explosion is also incurred.

(2) *Continuity of Supply.*

The only advantage derived from running with the N.P. insulated is the possibility of maintaining the supply with an earth fault on one line. This advantage applies really to overhead lines only in which earth faults are not so liable to develop into short circuits as in cables. However, the fault will probably lead ultimately to the conductor burning through and falling to the ground. Therefore, although the possibility should be borne in mind *in war on grounds of expediency*, it is no justification for not conforming with the usual practice in normal times.

It must not be forgotten that the question of the safety of the system itself is closely bound up with that of continuity of supply. The less the damage done to the system through a fault, the less the cost of repair and the shorter the duration of interruption of supply. It is, therefore, far preferable to clear faults in the incipient stage rather than to wait for short-circuit conditions and the consequent greater shock to the system which this means. When a short-circuit occurs, the excessive current which has to be broken is very severe on the switch, owing to the large E.M.F. induced; the arc at the break is very persistent, and results in serious burning of the switch contacts, and in extreme cases the induced E.M.F. is so great that the switch is unable to break the arc at all, and an explosion results. Moreover, very large mechanical

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forces operate between conductors. Many cases have occurred in which oil switches have been destroyed, busbars displaced, and their supporting insulators broken. These effects naturally become more pronounced as the size of the system increases, and it may safely be asserted that on systems of moderate size, with overload protection only, it is practically impossible to clear short circuit faults satisfactorily.

In the case of overhead lines, with insulated N.P., an earth fault on one conductor is in parallel with the capacity of that line to earth, and in series with the capacity to earth of the other two lines. The connection with earth is frequently intermittent, or in the form of an arc, which, being shunted by a capacity, is unstable, and the continued extinction and reformation of the arc sets up high voltage surges in the system which are very severe on the insulation, and sometimes flash over insulators in other parts of the system with destructive effects.

All this trouble is avoided by simply earthing the N.P. through a suitable resistance.

(3) *Telephone Interference.*

Theoretically, unbalanced loads and unbalanced leakage and capacity between conductors and earth will produce a certain amount of inductive effect on telephone circuits, and this is so whether the N.P. is insulated or not. Overhead lines are naturally more troublesome than cables in this respect. But the chief cause of disturbances in telephone systems is leakage.

It has been pointed out above that, with the N.P. at the generating station earthed and perfect insulation of the lines, the only earth currents are those due to capacity, the most important being the triple harmonic currents. But as soon as an earth fault develops on a conductor these earth currents increase very much in value, and may affect telephone circuits in the vicinity. The inductive effect due to slight leakage is naturally rather more than it would be with insulated N.P., and from this point of view the insulated neutral point might be considered preferable.

Experience shows, however, that if sensitive leakage protection is installed, the line is invariably cleared before the interference becomes annoying. Moreover, the *E.C. Regulations require immediate steps to be taken to improve the insulation if the leakage current exceeds one-thousandth part of the maximum load current.*

But, if the N.P. is earthed on another part of the system (as in Fig. 3), the effect of the triple harmonic currents is generally sufficient to interrupt telephone communication for many miles around. For this reason *earthing at more than one point is forbidden by E.C. Regulations*, except in special cases, and then only with the concurrence of the Postmaster General.

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However, the necessity for multiple earthing only arises in the case of inter-connectors between two separate power stations, and this matter will be touched on briefly.

The connections are usually made through step-up transformers as in Fig. 4.

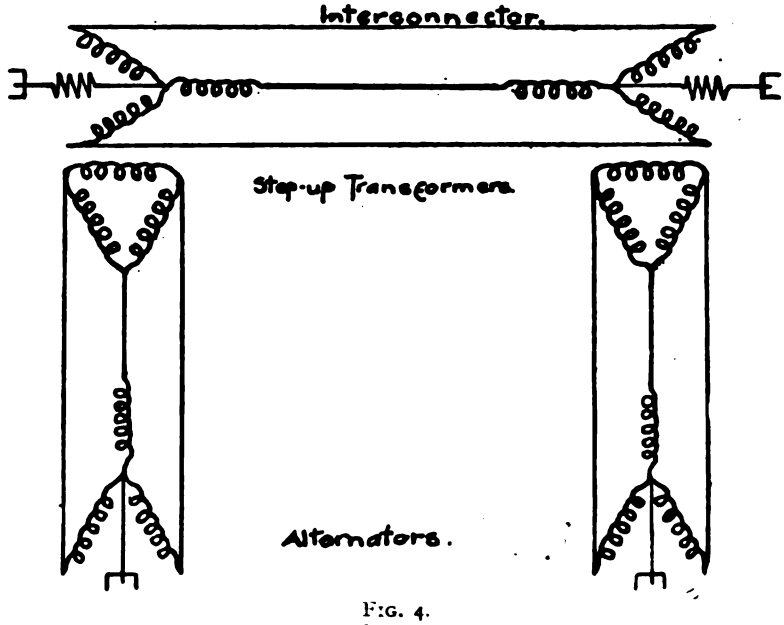

FIG. 4.

It will be noted that the alternator circuits are not electrically connected, and their neutral points are earthed direct, without any resistance.

Earthing the alternator N.P. in this case is not essential to the operation of leakage devices, but it prevents damage to the machine windings from excessive pressures which, under certain conditions, may be induced electrostatically from the higher to the lower pressure windings of the step-up transformer.

The N.P.s of both step-up transformer secondaries are earthed through limiting resistances, but the delta connected primaries ensure the absence of triple harmonic E.M.F.s in the secondaries. This arrangement ensures that the interconnector will at no time be left without an earth connection.

Multiple earthing on the above lines is sometimes approved by the E.C. and the P.M.G.

It should be noted in this connection that the telephone receiver is most sensitive to disturbances of a frequency of 800-900 cycles per second, therefore harmonics in the power system are much more troublesome than the fundamental.

The above remarks deal principally with "noise" in the telephones making speech difficult or impossible.

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It has also been proved conclusively that the telephone system is much less liable to have excessive pressures induced therein when faults occur in the power system, if the N.P. of the latter is earthed. This is, of course, due to the faulty power lines being cut off in the incipient stage.

The advantages of earthing the N.P. in H.T. systems may now be summarised as follows :—

(1) *Leakage Protection* can be installed, thus discriminating between overloads and earth faults, and enabling the latter to be cleared with a minimum of damage to the system.
(2) An overload line can be disconnected promptly if a conductor falls.
(3) Excessive pressure rises due to " arcing " earths are avoided.
(4) The factor of safety of the insulation is increased in the ration of $\sqrt{3}$ to 1.
(5) The system is not so susceptible to damage from atmospheric effects.

III. Earthing Arrangements.

It remains now to explain how the earthing is carried out. *Star Connected Systems*, being the more common, will be dealt with first. The case of a Single Alternator is simple (see Fig. 5).

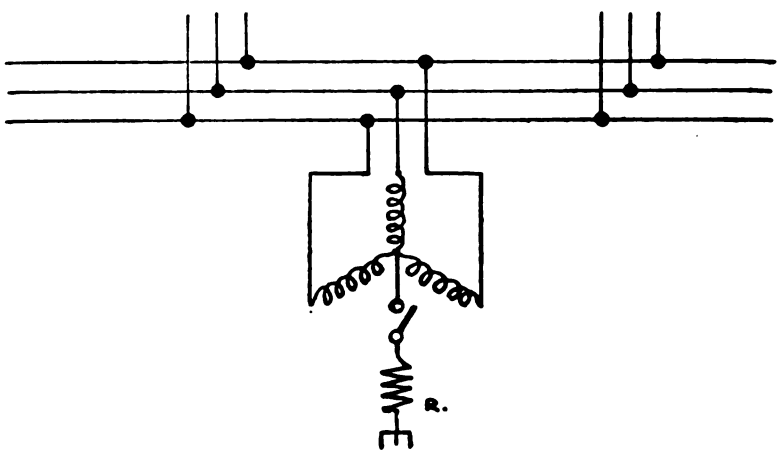

Fig. 5.

The N.P. is earthed through a non-inductive resistance R, and, if there is only one feeder, a trip coil can be inserted in the neutral connection, as shown in Fig. 2, but in the general case where there are a number of feeders, this arrangement will not do, as an earth fault on any one feeder will cut off the supply from the busbars by opening the generator main switch. The practical method

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is to instal a leakage trip on each feeder, making use of three current transformers and the current balance principle; see Vol. II, *Military Electrical Engineering*, p. 60 and Plate 26. This ensures that the faulty feeder only shall be disconnected.

When, as is more usual, several alternators are working in parallel, the matter is a little more complicated.

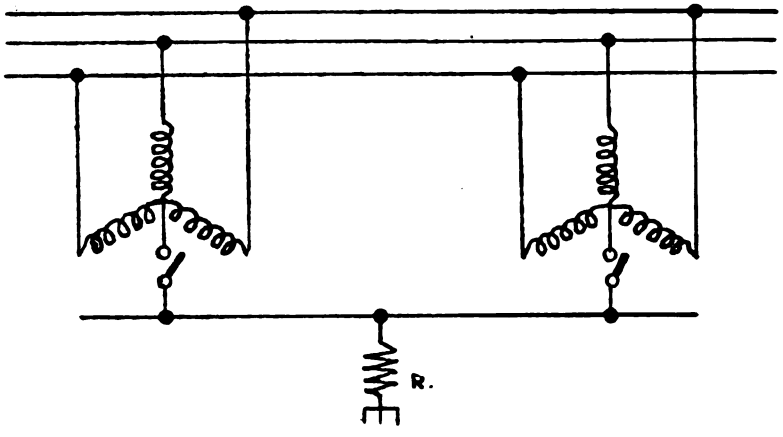

FIG. 6.

If the neutral points of the two machines are connected together solidly, as in Fig. 6, a complete path is provided for triple harmonic currents to circulate in the windings. In modern machines of similar design there is little to fear from this, but if the machines are of different make, the probability is that their triple harmonic E.M.F.'s are of different values, and the result will be an appreciable circulating current. But since the current divides between the three-phase windings in parallel, the heating effect of quite large currents is negligible. (A circulating current equal to 50 per cent. of load current does not increase the heating by more than 3 per cent.)

If, however, these circulating currents are found to be objectionable in their effects on measuring instruments and protective gear, they may be reduced in value by inserting a separate earthing resistance in each neutral connection to the earth bar (see Fig. 7).

In extreme cases it may be necessary to run with one generator only earthed at a time.

It is necessary to insert a switch (a disconnecting link will do) in each neutral connection to enable the machine to be completely isolated when necessary for overhaul.

Now, with regard to the value of the resistance it is impossible to generalise. The value should be such that the fault current to earth is sufficient to operate the leakage protective device on the heaviest feeder.

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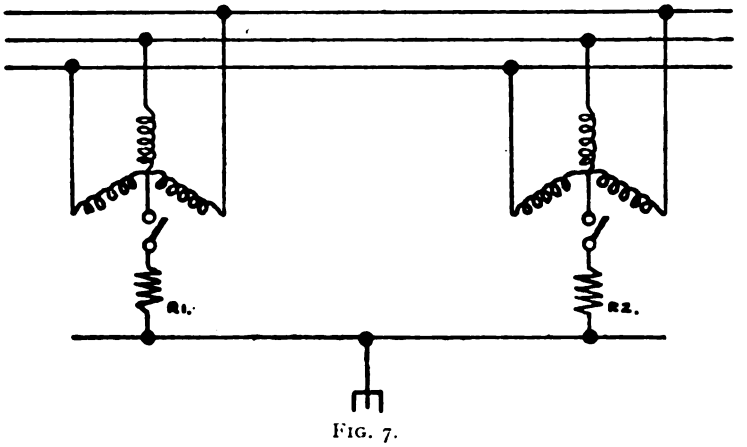

FIG. 7.

The E.C. Regulations lay down that if one of the conductors of an overhead wire makes contact with earth, the resulting leakage current must not be less than twice the value necessary to operate the leakage devices.

If leakage relays are used, a resistance limiting the fault current to 20 per cent. of the full load current of the feeder is quite suitable, since relays can be made very sensitive. But if simple leakage trips are installed without relays, the resistance must be much smaller in value.

When the arrangement in Fig. 6 is adopted it is usual to make R sufficient to limit the fault current to the full load current of the largest alternator. And when Fig 7 is used, the resistance in each neutral connection is made of such a value that the fault current through it cannot exceed the full load current of the machine to which it is connected. In the latter case the total fault current may exceed the full load current of one machine when several are working in parallel, and from this point of view it may be an advantage to run with the N.P. of one machine only earthed at a time. It is to be noted, however, in this connection, that all the oil switches in a generating station, whether on machines or feeders, are invariably of the same size, capable of dealing individually with the full capacity of the station.

The resistances must have sufficient heat capacity, and be installed in a fireproof chamber, to provide for possible delay in the working of the trip coil. It is usual to design them to carry a full load current for 30 seconds with a rise in temperature not exceeding 300° C. Insulation must be provided for full phase pressure.

The *Metal Grid* type of resistance having a positive temperature coefficient, the fault current tends to fall away rapidly if unduly

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prolonged. For this reason some engineers prefer to use a resistance of carbon which has a negative temperature coefficient.

Fig. 8 shows how the fault current varies with the time of its duration.

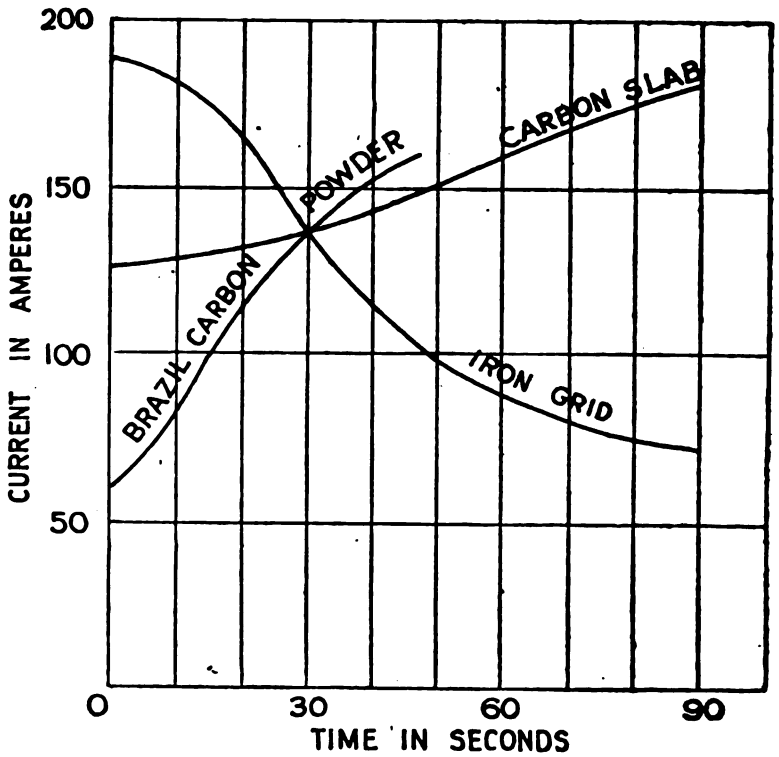

FIG. 8.—VARIATION OF FAULT CURRENT WITH TIME.

The "*Brazil*" type of carbon resistance consists of a number of fireclay troughs with carbon terminals at each end, the space between these terminals being filled with a special carbon powder. This form suffers from the disadvantage that excessive currents unduly prolonged tend to alter the value of the resistance permanently. Moisture also has an adverse effect.

The *Carbon Slab* type of resistance, it is claimed, entirely overcomes these disadvantages. This type consists of a number of solid carbon slabs fitted with terminals at each end, and protected against moisture by a coating of vitreous glaze. The slabs are perforated to accommodate porcelain insulators which rest upon one another, the whole being mounted on strong dome-shaped insulating supports (see Plate 2). The insulators also carry grooved channel pieces for the reception of the busbars necessary for grouping the various slabs in series or parallel, according to requirements.

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The construction is simple and robust.

Compared with the metal grid type, the carbon resistance appears to have the following advantages :—

(1) *Negative temperature coefficient.* This ensures that the fault current starts at its lowest value and gradually increases until circuit breaker opens.

(2) *It can be left in circuit much longer without damage.*

(3) *Smaller space occupied.*

(4) *Somewhat cheaper.*

(5) Simpler to carry out re-grouping of the units and to add more units when modification is found necessary.

The metal grid type is used most extensively at the present time, the reason being that engineers have been acquainted with this type of resistance construction for many years, but the carbon slab type will, doubtless, be used a good deal when its advantages are fully appreciated.

Plate 1 illustrates a metal grid resistance designed to carry an initial current of 160-170 amps on a 6,600 volt system. It has resistance of about 23 ohms total, and is suitable for use with a 1875 K.V.A. Alternator.

The approximate cost of the complete apparatus, as illustrated, in X.P.M. cubicle, and fitted with a disconnecting link, is £70. Its overall dimensions are 9-ft. high, 5-ft. wide, 2-ft. deep.

Plate 2 illustrates a carbon slab resistance to carry 150 amps on a 6,600 volt system. It has a resistance of 25 ohms and is, therefore, suitable for a 1875 K.V.A. machine. The space occupied by the resistance itself is 2-ft. 6-in. high × 2-ft. 6-in. wide × 2-ft. 6-in. deep. The overall dimensions of the X.P.M. cubicle with disconnecting link would probably be about 5-ft. high, 3-ft. wide, 3-ft. deep.

The cost of the *resistance alone*, as illustrated, is about £40. (It is made up of a 50 amp. unit in parallel with a 100 amp. unit).

The following examples of metal grid resistances actually installed may also be noted :—

(1) 3,300 *Volt* 1250 *K.V.A. Alternator.*

Resistance 14.9 ohms. Overall dimensions as above (including disconnecting link), 7-ft. 6-in. × 3-ft. × 1-ft. 6-in.

(2) 6,400 *Volt* 16,667 *K.V.A. Alternator.*

Resistance 2.5 ohms. Overall dimensions as above, 7-ft. × 5-ft. × 3-ft.

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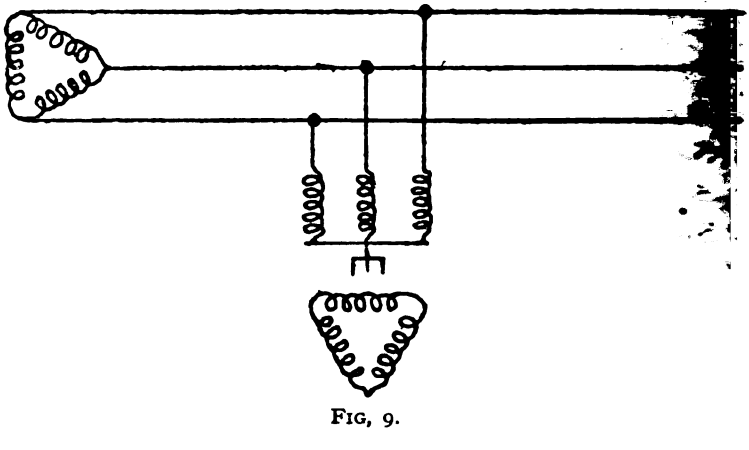
Delta Connected Systems.

In a Delta-connected system, an artificial neutral point can be obtained in the following manner :—



FIG, 9.

If an ordinary type of *Star-connected 3-phase power transformer* is connected to the busbars, the star point provides a suitable neutral point for earthing purposes. Although not essential, it will be an improvement if the secondary winding is mesh-connected and left isolated on open circuit (see Fig. 9). When faults occur, the currents circulating in the mesh cause the fault current to divide approximately equally between the three primary phase windings and reduce the effective impedance of the apparatus. The result is that for a given fault current a smaller transformer can be used than would be necessary if the secondary winding were absent.

Three separate single-phase transformers may be used instead of a three-phase transformer, but in this case the mesh connection of the secondaries is absolutely essential, since the three phases are not interlinked magnetically. Without the secondary, if a dead earth occurs on one line, the primary winding of the transformer connected to that line will be short-circuited and cease to function. Therefore, although the pressures across the primaries of the other two transformers increase from V to $\sqrt{3}$.V, the resulting current through the earth connection will be only a relatively small magnetising current. In a 3-phase transformer a pressure is maintained in the short-circuited winding by the interlinking of the magnetic circuits.

With regard to the size of this earthing transformer, a suitable continuous rating would be of the order of 2 to 3 per cent. of the maximum normal load on the largest feeder. For a 250 K.V.A. feeder, a 5 K.V.A. transformer would be quite big enough. At a line pressure of 6,000 volts, the maximum feeder current would

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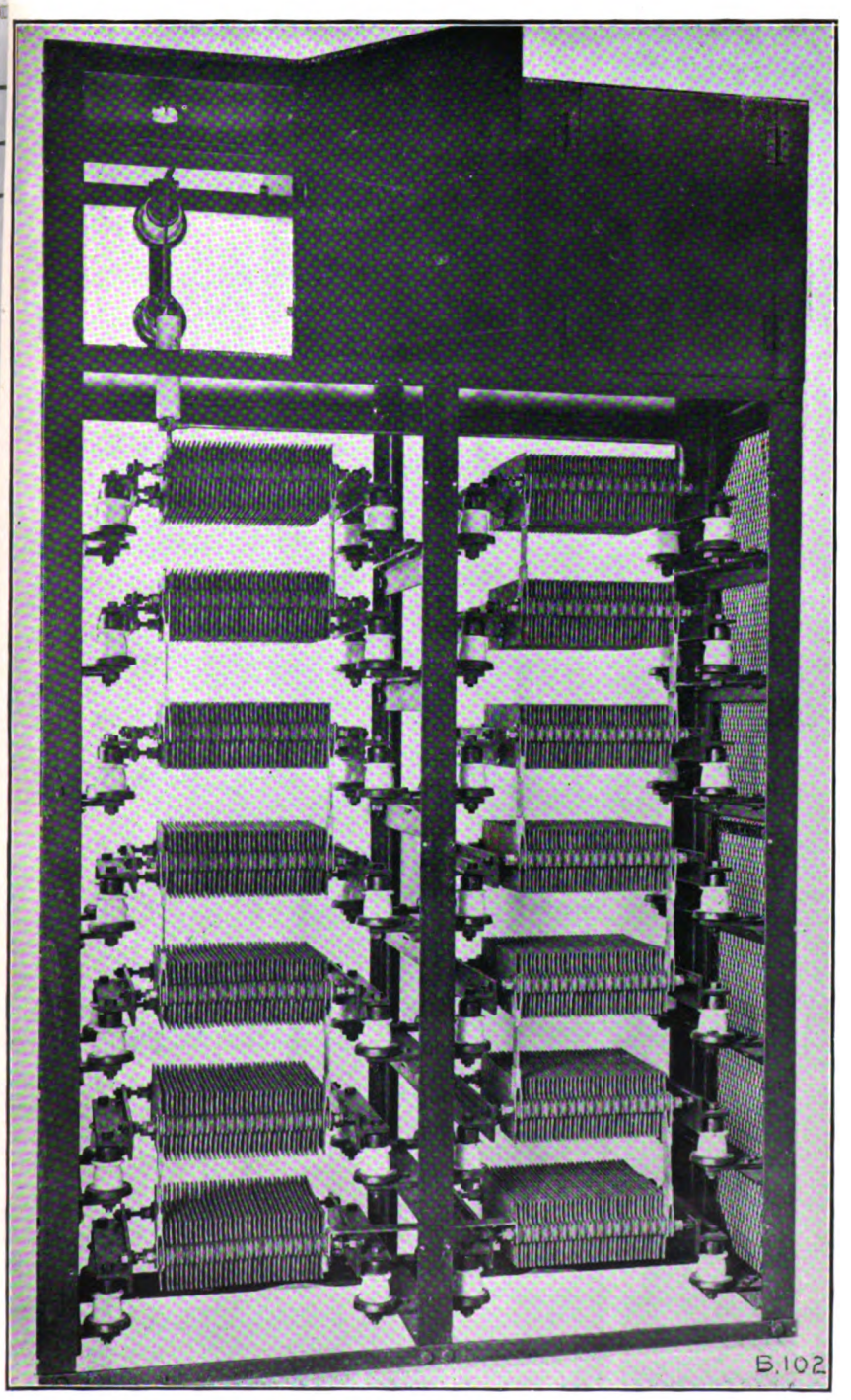
MODERN PRACTICE IN E. & M. ENGINEERING.



Neutral Point Earthing Resistance. Metal grid type. 6,600 Volts., 170 Amps. Overall dimensions, 9'x5'x2'. (Ferguson, Pailin, Ltd., Manchester).

PLATE 1.

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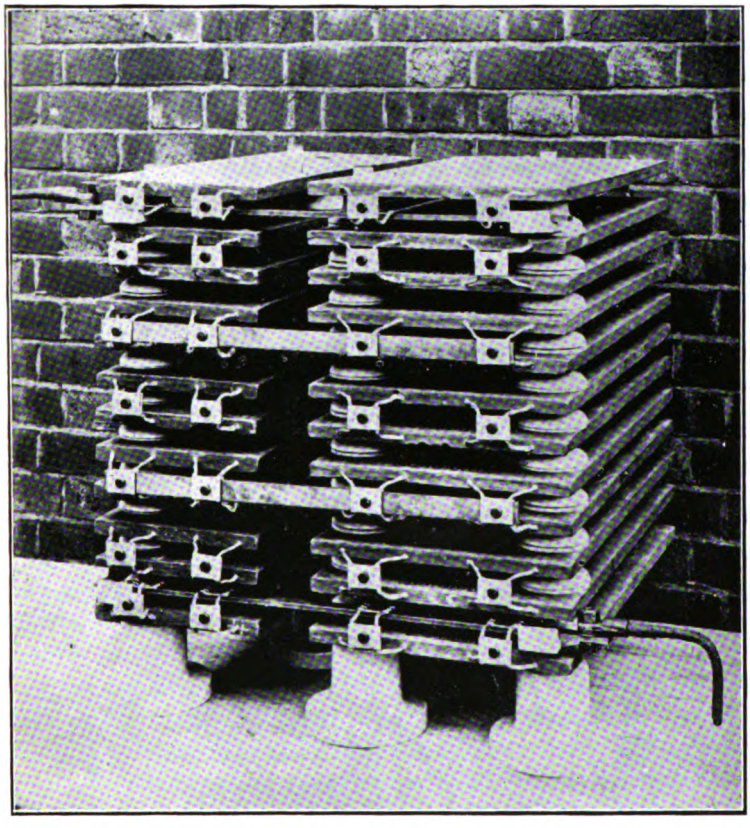

Neutral Point Earthing Resistance. Carbon slab type. 6,600 Volts., 150 Amps. Overall dimensions, 2′6″x 2′6″x 2′6″. (Everett, Edgcumbe & Co., Ltd., London)

PLATE 2.

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be 25 ampères, full load transformer current 0.5 amps., and the transformer would pass a fault current of 4-5 ampères for 30 seconds comfortably. This should be amply sufficient to operate a leakage relay.

When working normally, on a sound system, the earthing transformer would take a no-load current of about 0.15 ampère per phase, and the iron losses would be about 120 watts.

The above indicates the line of action which might be taken if a suitable earthing transformer is available, but if it is intended to purchase suitable apparatus, it will be found cheaper to obtain what is known as an "*Inter-connected Star Earthing Compensator.*"

This apparatus is built like an ordinary transformer, but has only one inter-connected star winding (see Fig. 10).

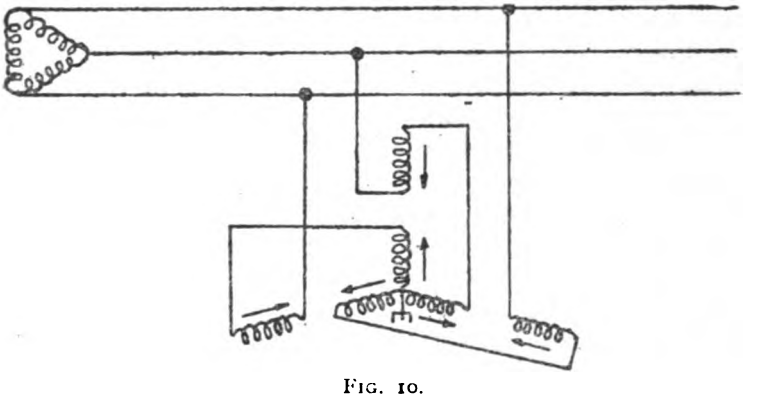

FIG. 10.

The fault current divides equally between the three phases, and as the magneto-motive forces cancel out on each limb, the windings act as if they were non-inductive as far as the fault current is concerned.

The apparatus can be designed with sufficient reactance to limit the fault current to a safe value, but for large sizes it is generally cheaper to use non-inductive limiting resistances. When there are no faults on a system the transformer takes simply a magnetising current similar to the Star-Delta type of earthing transformer referred to above, or to any other transformer with the secondary on open circuit.

The above described method of obtaining an artificial neutral point is, of course, quite suitable for star-connected systems as well; the only objection being the waste of power due to the iron losses.

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THE LIFE AND WORK OF COLONEL CLARKE.

By Colonel Sir Charles Close, K.B.E., C.B., C.M.G., F.R.S.

During the meeting of the British Association at Southampton in August, 1925, the President of the Association, Professor Horace Lamb, F.R.S., unveiled a tablet on No. 21, Carlton Crescent, to commemorate the fact that Colonel Clarke had lived in the house for twenty years. The tablet bears the inscription, " In this house from 1861 to 1881 lived Colonel A. R. Clarke, C.B., F.R.S., R.E., who determined the Figure of the Earth." *The Times* of August 28th had an article on Clarke's work with the title " An English Pioneer," and this article gave a brief account of his scientific labours. After Clarke's death an excellent two-page notice of his career was written, for the *Proceedings of the Royal Society*, by the late Colonel E. H. Hills, F.R.S.; but this account is not generally accessible to officers of the Corps, and it is thought that it might be of interest to record in the *R.E. Journal* a somewhat fuller notice of the life and work of a brother officer who was so distinguished in that branch of science to which he devoted his active life.

On the extreme northerly coast of Scotland, in Sutherland, not far from Cape Wrath, there will be found marked on the maps an inlet of the sea named Loch Eriboll, and it was in this neighbourhood, near the south-east end of the Loch, that there lived the old Scottish family of Clarke. Colonel Clarke's father, David Ross Clarke, of Eriboll, had gone out to Jamaica as a merchant, and, in 1827, married Eliza Hall, the daughter of Charles Hall. Their son, the subject of this memoir, was born at Reading on the 16th December, 1828. It appears that he must have returned with his parents to Jamaica at a tender age, for he used to tell his children stories of Jamaica, of which he could recall many memories. On leaving Jamaica the family returned to Eriboll and spent many years there, until they finally migrated to London for good, where, after several moves, they settled down in 35, Devonshire Place, W.; David Ross Clarke died there in 1861.

Of his youthful days in Scotland the Revd. A. Mackay-Clarke, his eldest son, writes: " I do not know what schooling he had in

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those young days, but remember his telling me of a 'dominie' putting him under his desk and kicking him from time to time, also how 'taws' were used. Anyway he learned Latin and Mathematics."

Alexander Ross Clarke, the future geodesist, when he was seventeen, suddenly formed the desire to join the Army, and went up for the entrance examination for the Royal Military Academy, after only about three weeks' preparation. The time available for preparation for this examination was insufficient; he passed in, but was last on the list. Once at Woolwich, however, his natural ability asserted itself; he rapidly rose in his batch and passed out first, being commissioned as a second lieutenant in the Royal Engineers on the 1st October, 1847. There has survived of his work at this period a little green pocket book, containing text-book examples of conics and Cartesian geometry; it is a model of neatness. On leaving Woolwich he went, in the usual course, to Chatham. The order, from 84, Pall Mall, runs thus: "You are granted leave of absence to the 1st November, on which day you will join the Field Instruction at Chatham, and report yourself to the Director of that Establishment, previously appearing at this office in Regimentals . . . . E. Matson, Asst. Adjt. General." A note is attached to the order that, "Every officer of Engineers is to provide himself with a proper case of drawing instruments, a telescope, box of colours and hair pencils, fifty-feet tape, a small sextant, and a pair of eighteen-inch parallel rulers."

He seems early to have made up his mind that the Ordnance Survey would provide scope for his mathematical abilities, for he approached Colonel William Reid, C.R.E. at Woolwich, a veteran of the Peninsula, who had himself served for some years on the Survey under Colby. Reid wrote to Colonel Hall, then Director of the Survey, and Hall replied in the following terms: Southampton, 4th January, 1850. "My Dear Reid, My funds for the year ending the 31st March next do not admit of my increasing the present number of officers on the Survey. From the 1st April next we are to have a separate vote of £2,000 per annum for the preparation and publication of the Trigonometrical Survey, and I will bear your recommendation in mind regarding Lt. Alex^{r}. Ross Clarke and speak to Matson about him."

Hall was as good as his word, and Clarke was posted to the Ordnance Survey, at Southampton, in April, 1850. But in 1851 he was ordered to Canada, and remained there until 1854, when he returned to the Survey. He remained on the Survey at Southampton for 27 years, i.e., until 1881, when he retired. All his geodetic work was done at Southampton. The "separate vote of £2,000" was perhaps the best spent money in the history of the Survey.

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Clarke, then, was posted to the Survey in 1854, and no doubt was immediately put on to the work of discussing the Great Triangulation. In 1856 he was placed in charge of the Trigonometrical and Levelling Departments. The last observations of the triangulation had been taken in 1853, but the work was practically complete in 1851. Anyway, when Clarke re-joined at Southampton in 1854, the field work was finished, and the time had come for the immensely laborious task of reduction. Now, at that time, there were no accepted methods in Great Britain of dealing with such a mass of observations. Clarke was able to study the methods in use in France and Germany, and perhaps in India, but the problem was not quite the same as in those countries; for one thing, the triangulation of the United Kingdom had been carried out in the form of a network covering the Islands completely, whilst abroad the system in general use was that of meridional and longitudinal chains. No reduction of a general or systematic kind had been attempted before Clarke's arrival. He accomplished the task with extraordinary thoroughness and rapidity, for the results were published in 1858 in a monumental quarto volume of some 800 pages, known as *The Account of the Principal Triangulation.*

Clarke, for the first time in this country, applied the principle of " least squares " to the computations in the most thorough manner. This principle, which is now of universal application in such computations, is due chiefly to Gauss, and consists in rendering the sum of the squares of the errors (or residuals) a minimum. It is noteworthy that in 1837, Airy, whose Figure of the Earth was shortly after that date adopted by the Survey, rejected this principle in his calculations for that determination. Clarke followed Bessel's *Gradmessung in Ostpreussen* closely. The network of triangles covering the British Isles was broken up into 21 figures, and the most complicated figure involved the solution of 64 equations of condition. The total number of equations of condition, for the whole reduction, was 920. Clarke's remarkable *Account of the Principal Triangulation* is not only a record of the computations, but it is, in itself, an exposition of the principles of, and a treatise on, geodesy. It contains the calculations for several Figures of the Earth, based on somewhat differing assumptions. The 1858 general figure is much used in British topographical surveys. The book contains much original matter.

In 1860, Struve, the astronomer, moved the Russian Government to invite the co-operation of the Governments of England, France, Germany and Belgium in the measurement of a longitudinal arc between Valentia Island, off the south-west of Ireland, in about longitude 10°30′ W, and Orsk in south-eastern Russia, in longitude about 58°30′ E; the arc covering about 69 degrees of longitude. As preliminaries for this undertaking it was necessary, first, to

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compare the various national standards of length, and secondly, to re-observe and render more precise the junction of the British with the continental triangulations. The comparison of the standards was entrusted to Clarke, who carried out the work in a building which was specially designed and constructed for the purpose at Southampton. The comparison included not only the standards of those countries mentioned above, but also the 10-foot bars for India and Australia. Tucked away in the volume which describes the comparisons will be found another discussion of the Figure of the Earth; the volume was published in 1866, and this figure is known as the 1866 Figure. This 1866 Figure has a considerable world importance. Every country is faced with the necessity of adopting some standard spheroid of reference. Thus in the British Isles it is Airy's Figure that was adopted; in India, Everest's, and so on. In the case of the United States, Clarke's 1866 Figure was chosen; and Canada and Mexico have, very wisely, followed suit. So that now, for the whole of the North American continent, the 1866 Figure is used.

In 1861 Clarke took part in the observations for the new connection of the triangulations mentioned above. The results were computed by him and published in 1863. In 1861 also he reduced and published the results of the spirit levelling in Great Britain. The reductions, by Clarke, were admirable; but the field-work left a good deal to be desired. It is now superseded by the geodetic levelling of 1912-21, so far as concerns England and Wales. In 1878 he again discussed the Figure of the Earth; this time on the assumption that the earth was not a figure of revolution, but was an ellipsoid with three unequal axes. With an assumption of this kind, which gives an extra figure of freedom, it is, of course, possible to obtain smaller residuals; but the hypothesis is by no means proved thereby, and we may look upon the computation as the amusement of a mathematician.

In 1880 he wrote his celebrated book on "Geodesy," which was published by the Clarendon Press. It remains the best English book on the subject, and may properly be described as a classic. In this book, also, he worked out a Figure of the Earth from new data, additional arcs having become available. The 1880 Figure also has its international importance. It is used by the French *Service Géographique de l'Armée* in all their recent work, and was used by the late Sir David Gill for the triangulation of South Africa. There never was a geodesist who so persistently tackled the problem as Clarke did between 1854 and 1880. It may be of interest to put down his principal results. In the Table which follows, a stands for the semi-axis major of the ellipse of revolution, and c stands for the compression, or $(a-b)/b$ where b is the semi-axis minor. The lengths of a are given in international metres.

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Date.	Authority.	Semi-axis major or a in metres.	Compression or c.
1858	*Principal Triangulation.*—British data only.	6,378,257	$\frac{1}{269.15}$
1858	Do. Do., only making allowance for topographical deflection.	6,378,497	$\frac{1}{280}$
1858	*Principal Triangulation*, from all available data.	6,378,293	$\frac{1}{294.26}$
1866	*Comparison of Standards of Length.*	6,378,206	$\frac{1}{294.98}$
1880	Clarke's *Geodesy.*	6,378,249	$\frac{1}{293.46}$

The Figure used by the Ordnance Survey since 1837 is Airy's. In this Figure $a=6,377,542$, and $c=\frac{1}{299.33}$

In 1901, Helmert, the celebrated German geodesist, worked out, from gravity measurements, a Figure which gave; $c\ \frac{1}{298.3}$ The late Mr. Hayford, the American geodesist, in 1911, found these values derived from American measurements: $a=6,378,388$; $c=\frac{1}{296.96}$ Finally, in 1924, the Geodetic Section of the newly formed International Union of Geodesy and Geophysics recommended the use of Hayford's last Figure, namely $a=6,378,388$; $c=\frac{1}{297}$. Where the international metre may be taken as equal to 3.28084275 feet.

It was a very fortunate thing for the Ordnance Survey that Clarke came when he did and stayed so long. The older men of science had disappeared; Colby had left a few years before and was succeeded by an officer of no scientific ability. Drummond was dead and Portlock had gone in 1843, and there was no officer left who was capable of undertaking the difficult and laborious task of reducing the triangulation. It is only right to say that, during the greater part of Clarke's time on the Survey, that department was commanded by an officer—Sir Henry James—who, though no mathematician himself, did thoroughly appreciate the necessity for a sound mathematical foundation for the Survey, and in every way supported Clarke officially in his great labours. Though, it

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might be suggested by some that Sir Henry James himself absorbed some of the credit which was due to Clarke. But, on the whole, James as Director and Clarke as geodesist worked well together.

What was the effect on the normal work of the Survey of all Clarke's work? Well, the effect was largely indirect in stimulating and sustaining a high standard of precision. There was, of course, a direct effect also, which was chiefly this: the whole triangulation was welded into a perfectly consistent whole, so that geographical positions and linear distances could be used with the certainty that, whatever the extension of a piece of work, no discrepancies could occur. The day was over for rule-of-thumb adjustments. Exactness and certainty took the place of the tentative and experimental methods of the past.

He was elected a Fellow of the Royal Society in 1862, but in later years the expenses of a large family obliged him to cut down his subscription list and he resigned from the Society. But in 1888 the Royal Society did him the great honour of re-electing him as a Fellow, without the necessity of his paying any subscription. In 1887 the President and Council of that Society had awarded him a Royal Medal for his "Comparison of Standards of Length and Determination of the Figure of the Earth." In 1868 he was elected a corresponding member of the Russian Imperial Academy of Sciences. In 1871 he was elected an honorary member of the Cambridge Philosophical Society, in the goodly company of Huxley, Spottiswoode, Argelander and Helmholtz.

Much of his work was done in No. 21 Carlton Crescent, Southampton. Surrounded by a family of young children, he had the faculty of detaching his mind from his surroundings to such an extent that they could play in the room in which he was working without interrupting the current of his thoughts; though he made the stipulation that they should not address him directly.

Clarke might reasonably have expected to have succeeded to the next vacancy as Director of the Survey and to have served till he was retired for age. But, in 1881, when he was not quite 53, an official of a familiar type woke up to the fact that Clarke had been at a home station for 27 years, and he was ordered abroad, to a tropical station, as C.R.E. Clarke was a man of somewhat hasty temper, and, on receipt of this order, he at once sent in his papers. His retirement was approved and he was gazetted out. Immediately a storm of indignation arose in the scientific world and representations from influential quarters were made to the War Office. Of no avail! His retirement had been approved and must stand. A lesson must be taught those who cherished the illusion that any officer was indispensable.

But Clarke *was* indispensable. He was the one man fitted for the post that he had occupied with so much distinction for so many

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years. His successor in this post was a well-known officer, of charming personality, universally popular, but alas! without mathematical ability. From that time for a long period, the history of the Ordnance Survey is, from a scientific point of view, but a melancholy recital of mediocrity. But officialdom in those days was of opinion that it was necessary to enforce the great principle that one officer was as good as another. Clarke's retirement was a veritable disaster for the Survey, and his departure lowered the whole tone and scientific status of the department for many a long year.

After his retirement he was appointed one of the British delegates to the Geodetic Congress which was held in Rome in October, 1883, the Astronomer Royal being the other delegate. But after that year he seems to have given up most of his scientific work. He appears to have published nothing more except some articles in the *Encyclopædia Britannica*, although he lived for more than thirty years after his retirement. In 1884 he was nominated as one of the British members of the International Geodetic Association, but it does not appear that he took any active part in the affairs of that body. The writer of this account had occasion to ask Clarke a question with reference to some geodetic matter, a few years before his death. It was evident from his reply that, in his old age, he had lost all interest in the subject.

After retirement Clarke settled at Redhill. There is an account of a visit paid to Clarke by the Russian geodesist Witkowsky. It is too long to quote in full, but the following extracts may give some idea of the manner of Clarke's life in retirement. Witkowsky writes: "My object in going to Redhill was not to enjoy nature, but to visit the well-known English geodesist, Alexandre Clarke. Arrived at Redhill, I walked confidently from the station along the main street, and though unaware of Clarke's address, thought that his house would be pointed out to me by any of the passers by. I was mistaken, the same as in Hamburg whilst searching for Repsolde, and came to the conclusion that no one could be a Prophet in his own country. Clarke's name seemed unknown to the residents of Redhill."

However, he found the house and was told that Clarke and his daughters had gone to church; he was asked to come in and shortly afterwards Clarke arrived; "Soon a ring announced the Master's return and in a few seconds I was in the embrace of my respected elder, he received me as a relative. From future conversations I came to the conclusion that even in England great men are not always appreciated by their worth." This must have been in the year 1898, for the writer goes on to say that "notwithstanding his 70 years Clarke continues to work, and is chiefly interested in scientific questions appertaining his speciality . . The translation of his works into the Russian language has afforded him great

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pleasure. Besides science, like many other learned English, Clarke takes a deep interest in religious subjects." The Russian geodesist had dinner with the family and after dinner " My sense of hearing was soothed by the Psalms sung and music played by them (Clarke's daughters) on the pianoforte. In every respect I was made to feel perfectly at home. My host not being able to continue his astronomical studies for want of an observatory, turned his attention to microscopical objects, and says that in them, there is as great grandeur as in anything else in the universal space. Here he comes into contact with some interesting mathematical problems. For lighting the microscopical apparatus he has a small kerosene lamp with a bluish glass; such a glass absorbs the heat-rays and keeps both the microscope and apparatus cool. Whilst inspecting the library Clarke enquired if I knew how many paints were required to paint a large map, so that each country should be of different colours, and that the same colours not clash. It appears that four paints would be quite sufficient, and a proof of this rule is a difficult problem. . . .

Our farewell was very touching, all the Family escorted me to the station and waved their handkerchiefs until a turn in the railway hid them from my sight. So I left peaceful Redhill, the residence of the respected Geodesist famed through England (? Europe) but not sufficiently appreciated in his own country."

The chief contributions of Clarke to the literature of geodesy are : *The Account of the Great Triangulation* 1858 ; *The Accounts of the Levelling of England, Wales and Scotland,* 1861 ; *The Extension of the Triangulation into France and Belgium,* 1863 ; *The Comparison of Standards of Length,* 1886 ; *Geodesy,* 1880 ; articles on mathematical geography and on geodesy and the Figure of the Earth in the *Encyclopædia Britannica* ; there are some 16 papers on geodetic subjects mentioned in the Royal Society's *Catalogue of Scientific Papers.*

In 1853 he married Frances, daughter of the late Major-General Dixon, R.E.; she died in 1888 leaving eight children, five daughters and three sons. The writer of this account is indebted to the eldest son, the Rev. A. Mackay-Clarke, for much of the information therein contained.

Clarke died at Reigate, on the 11th February, 1914, aged 85, leaving behind him the reputation of having been one of the most distinguished geodesists that this country has produced, and the most eminent man of science who has ever served on the Ordnance Survey.

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PROFESSIONAL NOTES.

(Communicated by the Field Works and Bridging School, S.M.E.)

The Demolition of Railways.

The deliberate demolition of railways will include not only the destruction of bridges and culverts, but also that of the permanent way. In flat countries the latter may be the only possibility. In the Palestine campaign a great deal of valuable experience was gained in this type of demolition, from raids carried out on the Hedjaz Railway. An article on this subject appeared in the January 1919 issue of the *R.E. Journal*. With careful organization it is possible for both the demolition party and the enemy repair gang to attain a high rate of progress and such operations may well resolve themselves into a race between these two parties.

It was proved in Palestine that an ordinary clean cut in a rail was of little value. The ends are easily tapped together and a new length inserted as soon as a sufficiently wide gap has been made. A twisted or bent rail is a much more difficult matter and must usually be returned to the mills for re-rolling.

Two methods of producing this result are already known. One is to overturn the entire track; this requires a large party of men. The other applies only to steel sleepers and consists in placing a small mined charge of 2 lbs. of guncotton under the centre of a mid-rail sleeper. This has the effect of humping the sleeper and twisting the rails outwards.

Both are therefore subject to limitations and it was felt that if the ordinary guncotton charge could be so placed or adjusted as to produce a bend or twist instead of a clean cut, valuable information would have been obtained. Experiments have recently been carried out at Chatham on these lines.

A 60 foot length of single track with wooden sleepers, chairs, etc., as for a permanent line was laid for the purpose. Two types of 80 lb. rail were used, flat bottomed and bull-headed. Both behaved in much the same way. In every case a joint was attacked, fish plates and bolts being left in position, when placing the charge.

It was found:—

(1). That 2 slabs packed with clay and placed centrally on a joint will usually blow a jagged fracture 2 feet long, leaving no trace of fish plates or bolts. It makes little difference whether

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the charge is placed underneath or on the side. In the latter case, clay was packed out to the level of the bolt heads, to provide a good seating. Slight distortion of the rails may occur but is not to be relied on.

(2). That 2 slabs placed centrally on the bolt heads but without clay packing will usually blow a jagged fracture 1 foot long. The fish plates and bolts will be distorted but not entirely removed. The rails are unlikely to be distorted.

(3). That 1 slab on a joint (even when tamped) is insufficient to produce any effect with certainty.

It thus appears that guncotton is too shattering an explosive to produce a bend with any certainty, but that the most effective method is to use 2 slabs tied on the side against the bolt heads without any clay packing. The distorted fish plates and bolts take some time to remove.

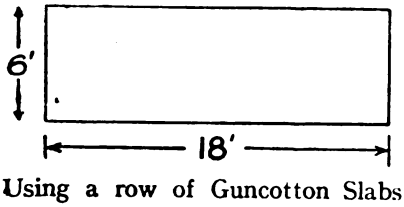
The charges should be staggered, alternate joints being selected on each rail.

Demolition of Masonry Piers by Means of Mined Charges.

This is a method of demolition which has perhaps not received the attention which it deserves.

The economy in explosives to be effected by the use of mined charges, instead of cutting charges, is very great and can readily be seen from a comparison of the respective formulæ in the following example :—

Cutting Charge.



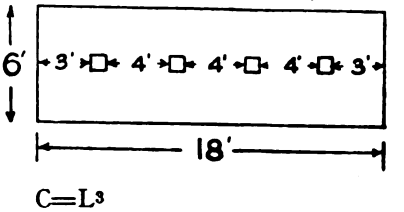
Using a row of Guncotton Slabs placed along one face of the pier.

$C = 2/3\ BT^2$

$= 2/3 \times 18 \times 36$

$= 432$ lbs Guncotton.

Mined Charge.



$C = \frac{L^3}{6}$

$= \frac{3 \times 3 \times 3}{6}$

$= 4\frac{1}{2}$ lbs. of ammonal for each charge.

Distance apart of charges

$= 4/3\ L = 4$-ft.

Hence number of charges is 4, and total amount of Ammonal—

$= 18$-lbs. Ammonal.

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There has hitherto been little or no data on which to base an estimate of the time required to prepare the boreholes, and it may be that many officers consider the operation much more lengthy than it actually is.

Experiments have recently been carried out at Chatham with a Miners Class in order to obtain some statistics of work of this nature.

The results are set out in the table below.

It will be seen that the preparation of the chambers is not necessarily a lengthy operation, and that this method of demolition may well be included under the heading of " hasty demolition " where the thickness of the pier is not excessive.

Time Required to place Borehole Charges in Masonry Piers and Quantity of Explosives Required.

Based on experiments carried out at Chatham with a Miners Class. Masonry selected was the brick lining to the Ravelin Ditch ; good class work in good state of repair.

Maximum length of bore-hole that could be driven was 3 feet, the limiting thickness of the wall. Times for longer boreholes are estimates only. In practice it is generally found that few piers are solid masonry throughout, the interior being usually rubble and fairly easy to work.

Thickness of Pier.	Spacing of Charges measured along face of Pier.	Weight of Ammonal for each Charge.	Suitable size of Borehole.	Length of Borehole required.	Estimated time taken by 3 men to make borehole and lay and tamp charge.	Remarks.
		lbs.			hrs.	Suitable Tools.
3′	2′	½	2″ diam.	1′ 8″	1	
4′	2′ 8″	1½	3″ ,,	2′ 2″	1½	Bars, jumping and boring.
5′	3′ 4″	3	4″×4″	2′ 8″	2	
6′	4′ 0″	5	5″×5″	3′ 3″	2½	Chisels, brick.
7′	4′ 8″	7	6″×6″	3′ 9″	3	Scrapers, Miners'.
8′	5′ 4″	11	7″×7″	4′ 4″	4	Hammers, Miners'.
9′	6′ 0″	16	8″×8″	4′ 10″	5	Sledge.
10′	6′ 8″	21	9″×9″	5′ 5″	6	Ditto, ditto, Boring.

Note.—If men are working from slung staging, increase time by 25%

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Approaches for Pontoon Bridges.

The introduction of the new pontoon equipment brings into prominence the question of approaches. The standard bridge is now the " medium " bridge designed for 5½ ton axle loads. This includes the 3 ton lorry and other mechanically propelled vehicles, which comprise the modern Divisional transport, also 6" howitzers and 6opr. guns.

Mechanical transport will normally be confined to roads and when it is found impossible to site a pontoon bridge giving direct access to metalled roads on both banks, auxiliary approaches will be necessary.

The site of a demolished bridge must normally be left clear for the construction of a stock-span bridge.

It follows, therefore, that the provision of a temporary crossing will generally include not only the construction of a pontoon bridge but also of a considerable length of approach on either side. The latter may well be the deciding factor in estimating the time required to complete the work.

It is thought that the following example of a typical case may be of some value to those officers who have not yet had an opportunity of handling the new equipment. The solution is entirely theoretical, the estimates being based to some extent on experience gained during instructional training at the S.M.E.

The estimate for the slab road will obviously depend very much on the amount of levelling to be done.

Problem.

It is required to construct a temporary crossing over the stream shown in the sketch. The crossing to consist of a medium pontoon bridge connected by slab road to the metalled roads on either side.

Data.

(1) The work to be carried out as quickly as possible.

(2) There is at present no access to E. bank.

(3) There will be one steel trestle at each end of the bridge.

(4) Banks are 3 feet above water level.

(5) The current is 3 knots.

(6) No interference is to be expected from the enemy.

SUGGESTED SOLUTION.

Unloading Stores. Carrying party for a pontoon = 24 men.

Take this as a unit party. Not more than 4 of these parties can work simultaneously without undue congestion.

∴Unloading party = 100 men (including N.C.O's.).

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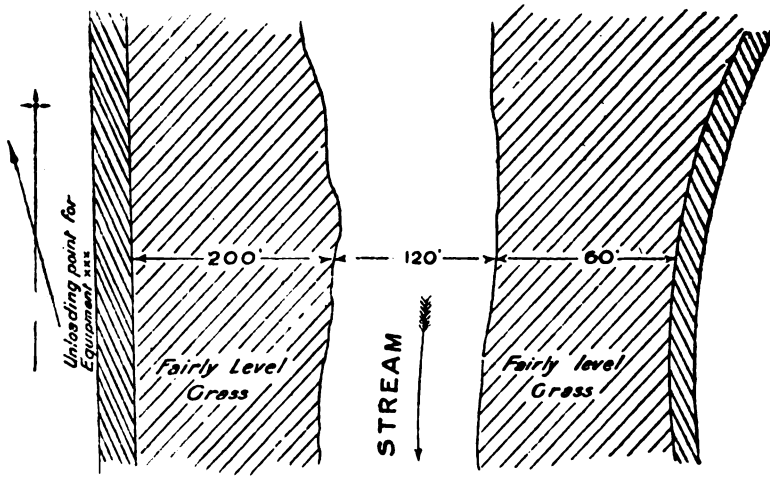
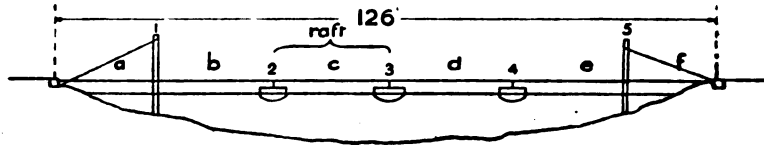


The Bridge.



Number of Party Loads.

2	Steel trestles—2 saddles	1
6	Pontoons	6
42	R.S.J's. and 6 Stiffening Transoms ..	10
176	9" x 3" Chesses	15
12	Ribands	1
6	Heavy anchors and cables	1
6	Buoys and Buoylines	
14	Shore baulks, spars	2
5	Saddles, lashings, cross-bracing, etc..	
		36=9 trips per party

Average time for trip and return, including unloading and launching in the case of Pontoons, say, 5 minutes.

∴ Total time for unloading is 45 minutes.

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CONSTRUCTION OF BRIDGE.

(*a*) *Trestles.*

The only justification for using trestles would be where the water was not deep enough to float a pontoon. (Tidal river need not be considered.) Hence the quickest method of erecting, will be to wade in and carry out.

Trestle No. 5 must be ferried over in pieces and assembled on East bank. Keep one pontoon for this as long as possible and for ferrying over men to start levelling for slab road on East bank.

Organisation.

Serial No.	Time.	Party.	Task.	Remarks.
1	Z+ 45 min. to Z + 1 hr. 20 min.	1 N.C.O. & 12 men.	Erect Trestle 1, complete Shore Bay and Span *a*.	
2	Z+45 min. to Z + 1 hr. 30 min.	1 N.C.O. & 12 men.	Ferry over Trestle 5 in parts on Pontoon No. 4. Assemble and erect. Insert 2 outer joists in span *f*.	
3	Z+45 min. to Z + 1 hr. 30 min.	2 N.C.O.'s & 26 men.	Construct Raft *c*. Come into bridge. Complete spans *c* and *b*.	
4	Z+1 hr. 30 min. to Z + 2 hrs.	Serial No. 1, 2 and 3.	Insert Pontoon No. 4 and complete entire bridge.	

Thus, to construct bridge, total party is 4 N.C.O's. and 50 men.

It appears then, that a suitable organization will be to divide the unloading party into two halves as soon as the pontoon equipment is unloaded. One half becomes the bridge construction party, the other half carries on unloading the slabs for the road.

In addition, a further party of 4 N.C.O's. and 50 men could be employed from Zero hour on levelling the foundations of the road, 3 N.C.O's. and 35 men on the West bank, 1 N.C.O and 15 men on the East bank, the latter party being ferried over on Pontoon No. 4 as soon as this is launched.

Slab Road.

Assuming that the ground is reasonably firm, drains can be left till later.

It is proposed merely to level off minor irregularities and to lay the runners direct on the grass. 6" nails are used instead of spikes, to save auger holes.

Forty-five minutes elapse before the pontoon wagons are unloaded and clear of the site, to enable the lorries to bring up slabs.

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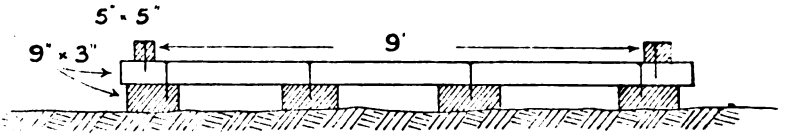
Adopting this type



Total slabs required=454.

weighing 15 tons.

=5 Lorries.

Unloading.

Fifty of the 100 men who unloaded the pontoon equipment will carry on unloading the slabs; the other 50 constituting the Bridge Construction Party.

Ten men per lorry should unload and stack in field alongside work in 20 minutes.

West Approach.

Serial No.	Time.	Party.	Task.	Remarks.
1	Z to Z+ 1 hr.	3 N.C.O.'s & 35 men.	Level foundations.	
2	Z+1 hr. to Z+2 hrs.	7 N.C.O.'s & 85 men.	Lay runners and complete road.	Serial No. 1 reinforced by slab unloading party on completion of unloading.

East Approach.

Serial No.	Time.	Party.	Task.	Remarks.
1	Z to Z+ 2 hrs.	1 N.C.O. & 15 men.	Level foundations.	
2	Z+2 hrs to Z+2 hrs 30 min.	12 N.C.O.'s & 150 men.	Lay runners and complete road.	Bridge and west approach completed at Z+2 hrs. All three parties available from this hour.

Summary.

One hundred and fifty men, with a proportion of officers and N.C.O's. should complete the work in about 2½ hours.

A suitable organization would be as follows.

Three parties. A, B and C, each consisting of

1 Officer
4 N.C.O's.
50 men.

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Time.	Party.	Task.	Remarks.
Z to Z+45 min.	A B C	Unload Pontoon Wagons. Do. do. do. Level approaches. 35 on west bank—15 on east bank.*	*Must wait a few mins. until a pontoon is available.
2+45 min. to Z+2 hrs.	A B C	Construct bridge. Unload slabs. Lay runners and slabs on west approach. Continue levelling approaches.	Bridge and west approach completed Z+2 hrs.
Z+2 hrs. to Z+ 2½ hrs.	A B C	Carry and lay runners and slabs on east approach.	East approach completed Z+2½ hours.

CAST-IRON HOUSES.

The following information was published in *The Times* of 1st October, 1925, about the cast-iron houses which are being manufactured by Messrs. Newton, Chambers and Co., of Sheffield :—

Some 11 tons of pig iron are used for each house. Blocks are moulded in the foundry, where there is a unique lay-out of moulding machinery. The cast-iron plates are joined together in the walls by bolts through the flanges, between which there is a wood-packing strip used for securing the internal linings. The outer walls are faced with a special cement roughcast. The houses with their red tiles and porches, seen against the background of the Yorkshire woods, are attractive in appearance. The opinions of the men employed in the works and collieries were ascertained before the houses were built, in order that they might be designed to meet the wishes of possible tenants. All consulted asked for a bath room to be installed upstairs. They asked, too, for good cupboards and picture rails in the downstair rooms. The kitchen has a range containing a roaster, a plate warmer, a hot closet, and a copper back boiler. The rooms are 9ft. high and therefore have more space than the majority of council houses.

The houses contain a living room, measuring 17ft. 10½in. by 11ft. 11in., a kitchen, 11ft. 3½in. by 9ft. 3in., a larder, 7ft. 11in. by 6ft. 3in., a coal place, 6ft. 3in. by 2ft. 8in., and on the first floor three bedrooms and a bath room. They are being delivered and erected within a radius of 50 miles, complete with internal fittings, fireplaces, bath, w.c., wash basin and hot water system, at £425. The increased cost quoted for erecting such a house at Brighton recently was £10. Arrangements have been made to supply these houses complete, to erect them and finish them for occupation without touching local supplies of skilled building labour. All the houses are built under building trade conditions. The price, of course, excludes the provision of foundations and drains.

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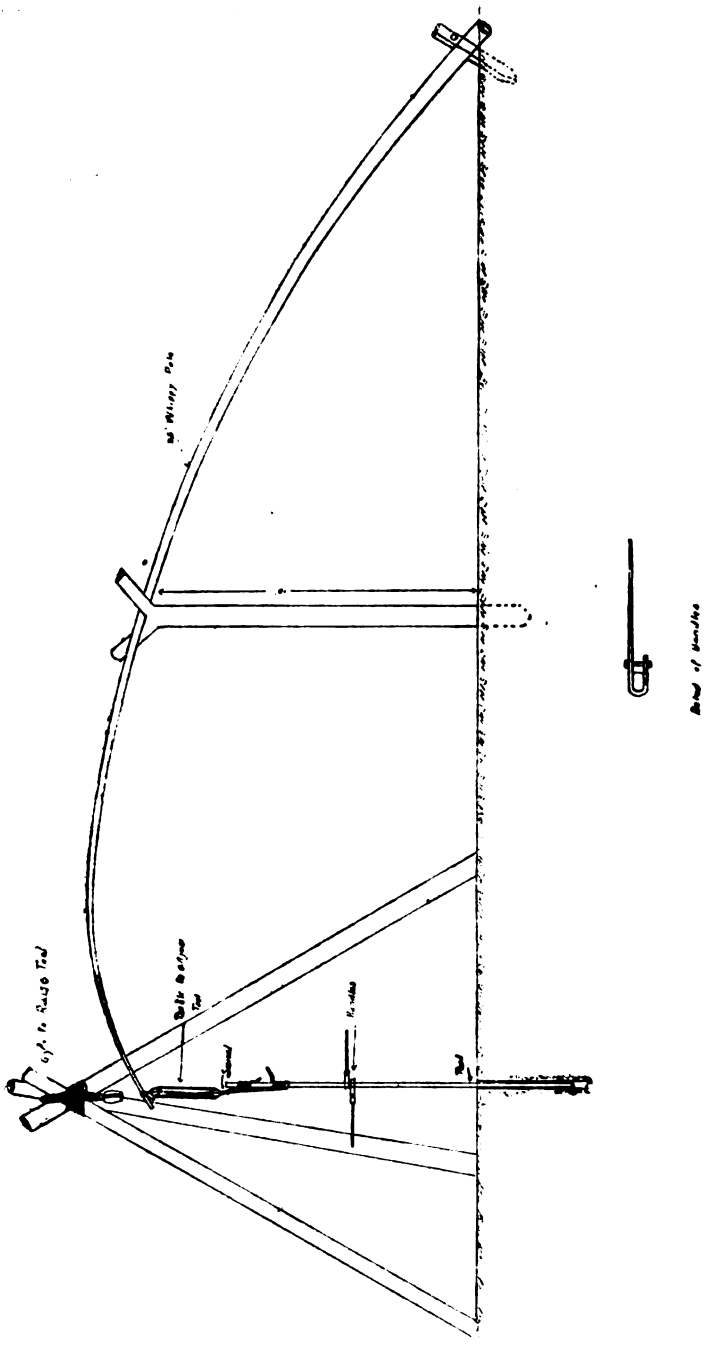

SIMPLE BORING PLANT

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SIMPLE BORING PLANT.

This apparatus is in common use in certain parts of Queensland where shallow wells are employed for watering stock. It is simple of operation, can be improvised in any ordinary circumstances, and as the bulk of the material can be cut from standing timber it is cheap and easy of transport.

It has been used with success to depths up to fifty feet or more, depending on the strata, and test bores can be sunk at the rate of from ten to fifteen feet per hour.

Its operation is as follows: Two men operating on the handles maintain a vertical oscillating movement of the tool, the whippy pole doing the bulk of the work. The tool can be turned in the bore by the men walking round as it is striking. The length of tool is adjusted by the tackle between the pole and the top of the tool, a gyn being provided to remove the tool as required. Fresh lengths are screwed on as the bore descends.

E. G. B. SCRIVEN, *Lieut.*
Staff Corps.

THE ROTOSCOPE.

Mr. A. J. Ashdown, of the Westinghouse Morse Chain Co., Ltd., Letchworth, Herts, has devised a new form of stroboscope for observing rhythmically moving or rotating objects having speeds ranging from the lowest to the highest met with in practical engineering.

The instrument is named the Rotoscope, and is so light and portable that it may be held in one hand when in use. A full description of the instrument is given in *The Engineer* of the 11th September, 1925, with illustrations and a general description of the principle on which all stroboscopes function.

The new Rotoscope allows binocular vision, and thus prevents strain on one eye, and as it is operated by clockwork, may be used in any position without preliminary setting up.

The shutter has a large range of speeds, from 500 to 20,000 per minute, giving a glimpse frequently up to 40,000 per minute, and a glimpse period as low as one thirty-three thousandth part of a second.

By means of this instrument the separate bars of a commutator may be clearly seen when passing any given point at the rate of 300 per second; a study can be made of the motion of the wings of a dragon fly, or the speed of rotation of a high speed turbine may be determined.

Engaging gear wheels of an engine may be studied or the slipping of belts in high-speed pulley drive. The instrument should add to the knowledge of the mechanical engineer.

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MEMOIRS.

SIR MONTAGU OMMANNEY, G.C.M.G., K.C.B., I.S.O.

SIR MONTAGU FREDERICK OMMANNEY, who died at Cuckfield on the 19th August, at the age of 83, received his first commission in the corps of Royal Engineers in January, 1864, and retired as a captain in 1878. He was born on April 4th, 1842, the son of Francis Ommanney, of York House, Worcester Park, and educated at Cheltenham and the R.M.A., Woolwich. From 1866 to 1870 he was employed on special duty at the War Office and Admiralty, and was one of the original members of the Council of the R.E. Institute, and, as we had reason to be reminded at the recent celebration of the Jubilee of our Institution, designed the Institute building at Chatham. In 1871 he became an instructor at the R.M.A. In 1874 he received his first appointment in the Colonial Office as private secretary to Lord Carnarvon. In 1877, on account of his previous experience as an engineer, he was given the new appointment of third Crown Agent for the Colonies, and, in 1900, was appointed, by Mr. Joseph Chamberlain, to the office of Permanent Under-Secretary of State for the Colonies, which he held until his retirement in 1907. He was a Vice-President of the Royal Colonial Institute and King of Arms of the Order of St. Michael and St. George. Of his work in the Colonial Office he will be chiefly remembered for his development of railways in the tropical colonies and dependencies. The following letter from Captain Frederic Shelford, M.Inst.C.E., formerly consulting Engineer for the Sierra Leone, Gold Coast, Nigeria, and other Government Railways, published in *The Times* of 1st September last, is a worthy tribute to his memory :—

The late Sir Montagu Ommanney had to deal with many problems when Permanent Under Secretary of State for the Colonies, the nature of which cannot be revealed, but his energy and business capacity left more outward and visible signs which may be more openly referred to. It was particularly due to his foresight that some of the Crown Colonies emerged from impoverished and neglected territories to prosperous dependencies with large revenues and sufficient assets to enable them to raise loans upon their own security alone. Sir Montagu's foresight, backed in particular by Mr. Joseph Chamberlain, led to the construction of the so-called Uganda Railway, which reached Victoria Nyanza in

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Sir MONTAGU F. OMMANNEY, G.C.M.G., K.C.B., I.S.O.

Photograph by KATHLEEN YOUNG, Cuckfield.

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1902. Sir Montagu served on the Committee of Management during the construction of this line. For many years it failed to pay its expenses on account of the paucity of traffic, but is now almost "snowed under" by the volume of traffic which the railway itself has created.

Another remarkable case is the Gold Coast. In 1899 I walked from Sekondi, on the Coast, to Kumasi through the tropical forest and back to Accra, and reported in favour of the construction of a railway from Sekondi to Kumasi, and later a railway from Accra to Kumasi. Owing to the business ability of Mr. Chamberlain and Sir Montagu Ommanney, the first of these railways was constructed. The usual conventions were brushed aside. The fact that the Colony could not raise a loan was not allowed to stand in the way. The interest on the cost of construction was guaranteed by those interested in the Colony, and the railway was built. In 1901 the revenue of the Gold Coast was about £400,000 per annum. In 1924 it was nearer to £4,000,000. The enormous development in the cocoa and other industries was entirely due to the construction of the first Gold Coast Government Railway in the first place, and then to the ability of the local Government and the enterprise of the natives in making use of the new means of transport.

The Colony of Sierra Leone also increased in importance by being the first to construct a railway, though its advance is not so exceptional, but when one considers Nigeria, the case of the Gold Coast is repeated on even a larger scale. It was in 1897 that railway construction was begun in this Colony in a tentative and cautious manner, but so immediate was the success achieved that length after length was added until Nigeria is likely to be covered with a network of railways before long. In most cases harbour works were undertaken at the same time. These railways, and there were others, were all remarkable for two features which required the courage of men like Mr. Chamberlain and Sir Montagu Ommanney to carry them through. First, they were built in spite of the fact that the Colonies had no money to pay for them, and in the faith that they would in due course pay. Secondly, they were built as "pioneer" railways, as more or less surface lines, avoiding deep cuttings and great engineering works, such as tunnels. This policy, which required great pluck and foresight, has resulted in these Colonies leaping into prosperity, but has had the natural result that those who came later have been compelled to improve the pioneer railways by reducing gradients and curves and making them nearer to the ideal railway, which should be level and straight. The original construction may have been reprobated for bad construction, but if these African railways had first been proposed as first-class main lines they could never have been constructed at all. In such cases as these, railways must be "planted" and be allowed to grow, as they have done, into good railways. Sir Montagu Ommanney had the foresight to believe in this policy and the pluck to carry it out.

Lord Sydenham writes:—"He was a first-rate public servant, and his training as an engineer gave him the practical turn of mind which administrators frequently lack."

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CAPTAIN MATTHEW HENRY PHINEAS RIALL SANKEY,

C.B., C.B.E.

M. H. P. R. Sankey came of an Irish family, the home being Bawnmore in the County of Cork. He was the son of the late General W. Sankey, C.B., and was born at Nenagh, County Tipperary, on the 9th November, 1853. He was consequently in his 72nd year when his sudden and lamented death took place at Ealing, on 3rd of October last. Sankey was educated privately at Woolwich and in Switzerland and entered the Royal Military Academy at the head of his batch in 1871. He had a most distinguished career at the "Shop." He passed out at the top of his batch and was the Responsible Under Officer of his term, thus winning both the Pollock Medal and the Sword of Honour. He received his Commission in the Royal Engineers on 29th April, 1873. Sankey's career at the S.M.E. was as distinguished as that at the "Shop." His extraordinary ability being at once recognised by all with whom he came in contact. My father, who was a subaltern at Chatham in those days, used to say in jest, that Sankey was the only man he ever met who appeared to be able to keep his private accounts by means of the Calculus. Sankey was not only a mathematician of the very highest order but also a very good linguist. Another of his early accomplishments, which I can personally remember, was that he played the violin.

Towards the end of his S.M.E. Course, Sankey was selected to assist in the conduct of the famous trials of continuous railway brakes, which were carried out by the Royal Commission on Railway Accidents in 1876, at Thurgarton, between Newark and Nottingham.

On leaving Chatham he was employed in the I.G.F's office for a time on architectural design and then went to Gibraltar for a tour of foreign service. While at Gibraltar he was appointed Instructor in Fortification, at the Royal Military College, Kingston, Canada. It was in Canada, where he arrived in 1879, as assistant to my father, that I first met him to know him. My father I know had the highest possible opinion of him both personally and professionally, but it was the personal side which attracted me. His energy and cheeriness were extraordinary. His joy in living was infectious; rowing, skating and similar sports seemed to come just the same as electrical measurements. I shall never forget one incident. Sankey had engineered a submarine mine, to be exploded electrically for the benefit of the spectators at the Public Day at the end of one of the College terms. The mine consisted of a length of cast iron water main filled with gun cotton and plugged at the ends. It was a very successful show and I well remember putting off in a boat, after the explosion, to gather the dead fish. To lay the mine, a big boat had been rigged with some tackle at the mast head, and the day after the show this had to be dismantled. The boat was moored beside

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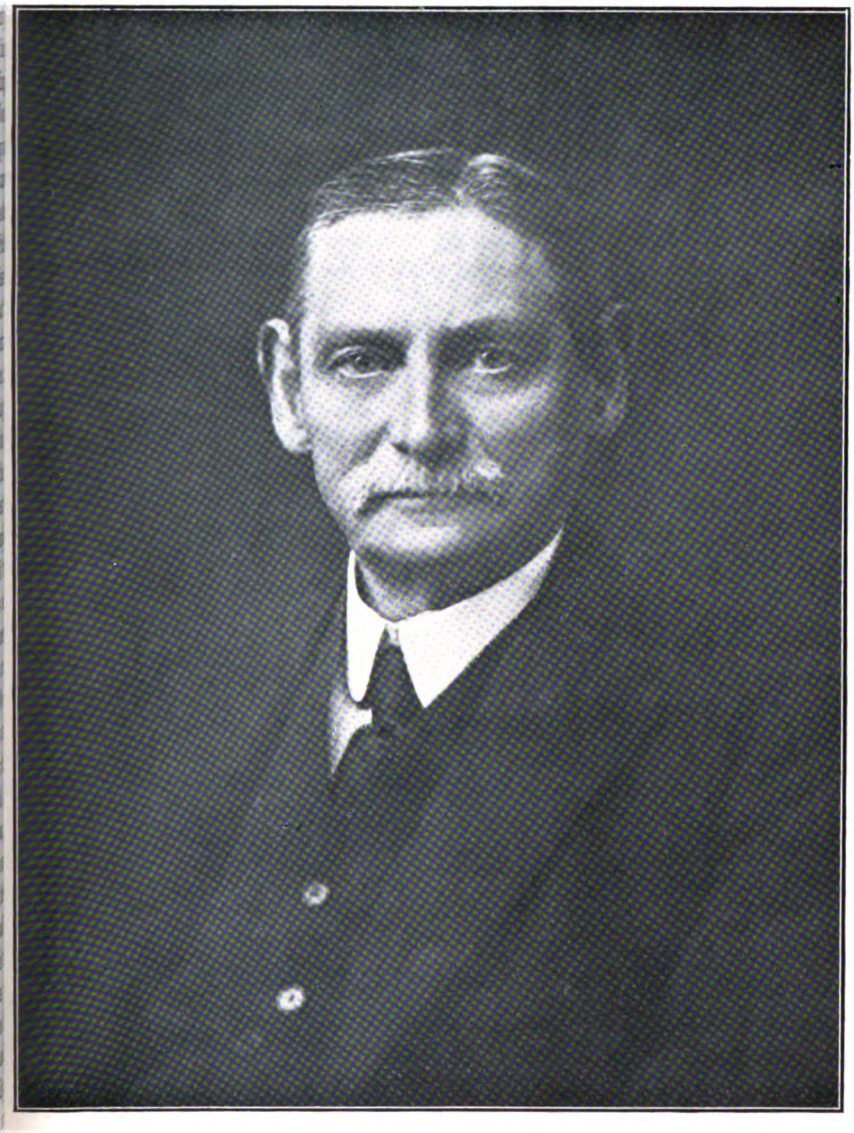

Captain M. H. P. Riall Sankey, C.B., C.B.E , R.E.

Photo, Russell, 73, Baker Street, London.

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the wharf at the back of the old (Frigate) barrack block of the College. My father, Sankey and a French Canadian gunner proceeded to take down the gear. I was an interested spectator in the boat. In spite of mild protests from my father, Sankey proceeded to climb the mast and the boat immediately turned turtle! Sankey went to the bottom with the mast and gear, my father disappeared under the boat, I and the gunner crawled up on to the keel as she turned over. Never shall I forget the scene. My father's face, scarlet with indignation, emerging from under the gunwale, Sankey suddenly emerging from the waves and the French Canadian kneeling astride the keel and praying, in an unknown tongue, to all the Saints in the Calendar to save him. When he saw we were all safe, Sankey at once started in a light-hearted way to dive from the wharf to try and recover some of the lost gear. I tell this story as the incident made a great impression on me. His behaviour was typical of the man; nothing could depress him. While at Kingston, Sankey wrote a book on Electrical Measurements for the benefit of the Cadets, and collaborated with my father in writing a book of notes on Fortification. I think amongst other things he drew all the pictures. I have a copy of these notes still and they seem to me to be about the best of their kind that I have ever come across, in that they enunciated, with the most unmistakable clearness, that the art of fortification was invented to help soldiers to fight battles and that such was its only object. One of the axioms laid down was that a work must be properly sited, that it should be of such dimensions that men could fire out of it, and that it should be bullet proof. I doubt if the whole art can be more succinctly described.

Sankey returned to England in 1882 and was posted to the Ordnance Survey at Southampton, as some one with electrical knowledge was required to perfect the system of the electrical deposition of copper, in connection with the reproduction of map sheets. This was done at that time by current supplied by Smee Cells. This was costly and it was desired to use a dynamo. Sankey succeeded in solving the problem and in course of his search for a high speed engine for the purpose, he came in contact with the Willans engine of the day and introduced it. This engine was not of the central valve type which became celebrated later. Another improvement in map reproduction which Sankey introduced, was the substitution of power for hand printing presses. This enabled the printing to be done on dry paper and obviated the necessity for the damp paper, used under the old system, and its consequent shrinkage and loss of scale.

In 1889 Sankey retired from the Service as a Captain and joined the firm of Willans and Robinson, engine builders, of Thames Ditton. As a result of his experience and investigations with this firm he wrote a paper on the *Thermal Efficiency of Steam Engines*,

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and another on the *Strength of Shafts Subject to Small Forces Rythmically Applied*, for which latter the Institution of Civil Engineers awarded him the George Stephenson Medal and Prize in 1905.

In 1904, Sankey resigned his directorship of Willans and Robinson and commenced practice as a Consulting Engineer, in which he was very successful. He later became Director and Consulting Engineer of Marconi's Wireless Telegraph Co., Ltd., and Marconi International Marine Communications Co., Ltd., which he held to the end of his life.

He became a member of the Institution of Mechanical Engineers in 1894, was a member of the Council, 1910-19, elected Vice-President in 1919 and President in 1920 and 21, two years in succession. He was a most active member of the Institution, both as a member of many scientific Committees and also as a contributor to contemporary literature, in connection with all kinds of machines and materials.

In 1895 he was elected a member of the Institution of Civil Engineers and took a very prominent part in the preparation of the original Standard Codes for the conduct of engine and boiler trials, and played a similar rôle in connection with the revised version, promulgated this year. For some years before his death he had served on the Council of the Institution and had been chosen as Vice-President for the coming Session. Had he lived, therefore, he would normally have become President of this great professional Institution also. Sankey had become a member of the Institution of Electrical Engineers in 1885, but never served in any office. In addition to the above, he was a member of the Iron and Steel Institute, the Institution of Naval Architects, the Institution of Gas Engineers, the American Society of Mechanical Engineers, and was for several years a member of the Governing Board of the National Physical Laboratory.

When the Great War came Sankey volunteered his services to the Director of Fortifications and Works at the War Office. His services were accepted and he was appointed a staff captain in the D.F.W's office. His work was invaluable, although he was left in the anomalous position of never being given promotion above the rank of Captain, with which he had retired. After all, as most of us know, it is not the rank but the man that matters and, if there ever was a man, it was Sankey. His employment was entirely honorary and he never received any emoluments for his work.

As Engineering Adviser to the D.F.W., he was an invaluable link with the Civil branches of the profession. During 1915, when War Office methods as regards Camp Construction were under

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criticism, the President of the Institution of Civil Engineers was asked to form a Committee to examine the work, and Sankey was the representative of the D.F.W. who was responsible for all the arrangements. Subsequently this Committee was called upon to advise upon all kinds of large works, such as the Loch Doon Aerodrome, Coast Defences, etc. In their reports this Committee frequently acknowledged their indebtedness to Sankey for his able assistance. Sankey also went overseas to Flanders in 1915, and devised a scheme for the drainage of water-logged trenches. This scheme was carried out by the 197th (Land Drainage) Coy., R.E. and resulted in a very great improvement in the condition of the works.

In 1918 he went out with Sir Maurice Fitzmaurice to report upon the possibility of inundating certain portions of the front. For the above services he received the C.B. (Civil). After the War he was a member of the Valuation Committee, which worked for years assessing the values of various munition factories, etc. For this service he received the C.B.E.

Sankey was married in 1876 to Elizabeth Mary, eldest daughter of General E. L. Pym, Royal Marines, and there were five children, two sons and three daughters. The younger son died in infancy, the elder is Lt.-Colonel C. E. P. Sankey, D.S.O., R.E. (*retired*), who is now the resident engineer in charge of the preservation of St. Paul's Cathedral.

The above is a brief, and I fear a very inadequate, summary of the story of Sankey's life in our Corps and as an Engineer in civil life. I should like, however, to say a word about the man, apart from his achievements, for it is the character of a man that matters to those who are left behind.

He was a perfectly straightforward, simple, God-serving Englishman; a gentleman to the tips of his fingers. He was thorough in his work, which he loved, and in the doing of which no trouble was too great, no detail too small. Many will testify to his kindness of heart. I have been privileged to read some letters of appreciation addressed to the Secretary of the Institution of Mechanical Engineers and they all are written in the same strain. They all emphasise Sankey's personal charm and unfailing solicitude for those who wanted help, besides deploring the great loss which the profession has sustained by his untimely death.

It was his cheerfulness, however, that always attracted me; no trouble seemed to depress him, and he had experience of trouble. He seemed to radiate cheerfulness and charm to all around him. In him was personified the saying that "the impossible is possible to smiling men."

G.W.

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COLONEL HORATIO DOVE.

COLONEL DOVE was the eldest son of the Rev. J. T. Dove, who for over 44 years was Vicar of Cowbit, in the Fens of Lincolnshire. This is recorded to emphasize a fact too little recognised. The Vicarage and the Manse have contributed one of its best elements to the fighting forces of the Empire. Sometimes it has risen to high distinction, more often it has just done its duty in a plain matter-of-fact way, but with a keen intelligence, a sturdy loyalty, and a hatred of the limelight, which have made it (even more than "the non-commissioned man") the backbone of the Army. And for the Senior Service it has done the same, as in this family. Colonel Dove's next brother went down somewhere in mid-Atlantic as First Lieutenant of the ill-fated training ship H.M.S. Atalanta, and he himself was a fine example of the type. Born on 30th June, 1849, and bred in a Curate's home in St. Marylebone, he knew nothing but simplicity in life, and as a day boy at Merchant Taylors, and afterwards at the R.M.A. in the '60's, his life was not exactly an easy one.

An excellent mathematician he passed out fourth of his batch, which included Sir Reginald Hart, V.C., and received his first commission in the Royal Engineers in January, 1869. After passing through Chatham in the ordinary course, he went out to India. He was there 10 years. During that time Dove saw active service in the Jowaki-Afridi Campaign of '77-8 and in the Afghan war '79-'80, and received for each the medal and clasp. He was also for several years working on the commission for the delimitation of the N.W. Frontier, much of the report being in his handwriting. On returning to England as Captain he was stationed at Preston, where in 1883 he married Annie, second daughter of Edmund Birley, Esq., of Clifton Hall. From Preston in 1885 he was ordered to Port Said and shortly after to Hong Kong, where he placed all the big guns round the harbour; from thence he went to Ceylon, and about '88 returned home and was C.R.E. at Edinburgh. Finally he accepted the post of C.R.E. Jersey on account of his wife's health. There she died, and there a few years later he married Mabel, daughter of Captain Gibson of the Indian Army.

On retirement Col. Dove resided at Leamington, where in May, 1915, he raised the local Fortress Company R.E. For 1916-17 he was recruiting officer at Budbrooke, walking to and fro daily to the further side of Warwick, and afterwards he did much duty as Special Constable in Leamington.

Though in his youth a good gymnast, of the old type, Col. Dove made no mark in athletics. Always a student he possessed a fund of learning which he would never air. Hating publicity he would not even talk of his experiences, and self-denying to a fault he would

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never spare himself; but where a task came his way he did it with complete thoroughness, fearing God, honouring the King.

His only child, a daughter, is wife of J. C. C. Coxhead, Esq., H.M. Vice-Consul at Elizabethville, Belgian Congo.

J.H.D.

COLONEL C. H. H. NUGENT, C.I.E.

Colonel Charles Hugh Hodges Nugent, who died at Naini Tal on 2nd December, 1924, was the son of Colonel Sir Charles Nugent, K.C.B., late Royal Engineers, and was born at Bermuda on 11th December, 1868. He obtained his first Commission in the Royal Engineers in 1888, and gained the Fowke medal at the S.M.E. After a course of training at the Elswick works of Armstrong, Mitchell and Co., he was employed in charge of machinery at Portsmouth, 1893-94, Ceylon 1894-95, Hong Kong 1896-99 and in the Thames District 1899-1905. During this last-named period he was Inspector of Iron Structures and Chief Mechanical Engineer to the War Office and was responsible for much of the equipment of the Imperial Military Railways in South Africa. As an original member of the War Office Committee on Mechanical Transport he had a wide experience in matters connected with self-propelled vehicles, heavy and light, and he took especial interest in the problems presented by the use of heavy oils for purposes of transport. From 1911 to 1919 he was Inspector of Machinery at Army Headquarters, India, at Simla, and during the War his activities included the formation and organization of mechanical transport and armoured car units in India, Mesopotamia, Aden and West Africa. He received the C.I.E. in 1916. His War Service included motor transport reconnaissance in Seistan and visits to several of the theatres of operations, and he also took part in the Afghan War of 1919. At the time of his death he was Chief Engineer Eastern Command, Naini Tal. Colonel Nugent married Jessie, daughter of the late Major-General Wray, C.B., Royal Artillery.

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BOOKS.

OFFICIAL HISTORY OF THE CANADIAN FORCES IN THE GREAT WAR, 1914-19.

VOL. I—THE MEDICAL SERVICES.

By SIR ANDREW MACPHAIL. Professor of History of Medicine, McGill University.

Published by authority of the Minister of National Defence.

This is a most delightful, interesting and instructive book without a single dull line in it. In the course of 400 pages it gives a connected history of the raising and activities of the Canadian Medical Service in all its branches, in a style and with a method adapted to the general, as well as the professional reader. Sir Andrew Macphail, when selected to write the book, was given access to all relevant official documents, but the inferences drawn and the opinions expressed are those of the Author himself. Sir Andrew was, therefore, in much happier and freer circumstances than are official historians in this country and the reader profits thereby. An order was happily issued on mobilization to the Canadian Medical Service (quite contrary to regulation) recommending officers to keep private diaries, and these have been at the disposal of the Author. Many extracts from them, often of a high literary standard, enliven the narrative. The account in Chapter VII of the march from the Salient to the Somme is consolidated from various of the diaries, and the result is a delightful and vivid description which must especially appeal to every reader.

The growth of the Canadian Medical Service from its inception is described, and it is interesting to find that in the pre-war years Sir Alfred Keogh, when D.G. A.M.S., developed a plan for unity of method in the Medical Services of this Country, the Dominions and India. The plan was followed in Canada and elsewhere with the happiest results: from the very beginning the various Medical Services of the Empire talked, as it were, the same language, and worked together with the utmost cordiality and mutual help.

The Canadian Medical Schools and Hospitals had long been renowned, and every effort was made to construct a Medical Service that would be the best in the Army. It certainly was second to none, and the writer remembers the thrill he had when visiting, in 1917, No. 3 General Hospital, the especial product of the McGill University.

The work of the Canadian Medical Services is admirably told in general terms and the functions of the various organizations described in a way that gives the reader never a tedious moment, whilst all is made so clear that understanding is never at fault.

There is a special interest in Chapters XI to XVI, which deal fully with the effort made by Sir Sam Hughes to segregate the Canadian Forces in general and the Medical Services in particular: these efforts failed,

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accompanied by the downfall of the Minister. In the attempt to keep the Canadians to themselves reckless statements were made, casting a slur both on the Canadian and British Services, which were wholly without foundation, but which required a special Board of Officers to clear up. Segregation was in itself impossible from a practical point of view, and "the facts would have risen to the surface without the injection of sentiment." The Sentiment arose of itself and carried the day: viz., that "the bonds of Empire would be strengthened by the intermingling in hospitals of men from all forces of the army, as they had intermingled, comrades on the field." The comradeship and cordial interworking of the British and Canadian Medical Services were pronounced from start to finish, and every English reader of this book must feel gratified at the tributes paid throughout to the help extended at every juncture and in every service by England to Canada.

H. M. LAWSON,
Lieut.-General.

MILITARY ENGINEERING (Vol. II) DEFENCES. 1925.

This is a booklet of 99 pages with 27 Plates, divided into *Land Defences* and *Coast Defences*.

The *Land Defence* section opens with a short review of the past up to 1914, devotes brief paragraphs to Liège, Namur, Antwerp, Maubeuge and Verdun (1916), and after a reference to trench warfare which lasted so long, not only on the Western front, but in Eastern theatres also, draws general conclusions as to Permanent Land Fortification today.

Emphasis is laid, properly, on (*a*) mobile heavy artillery; (*b*) trench systems and wire; (*c*) defence in depth. Material preparations during peace in the case of important strategic areas and positions are limited to such items as maintenance of open fields of fire, communications (physical and signal), storage, shell-proof dug-outs for H.Q. of formations and troops, O.P's., landing grounds and protection of air-defence-organisation, anti-tank obstacles and mines. The last item perhaps is more of a aspiration than a realisation at the present time: in fact, later on (page 45) it is stated with much truth, "Various types are at present under consideration."

In the description of concrete shell-proof dug-outs there is an important omission from the "principles of construction," viz.:—the necessity for substantial reinforced concrete *floors*. The plates shew correctly this important feature, but the letter-press omits it.

Land Defence closes with a chapter on organisation and execution of work, in which good use has been made of the experience of March-July, 1918, in France.

Coast Defence opens with a few definitions and general methods of enemy attack. A short historical review is given from Gibraltar (1782) to Port Arthur (1904), which is followed by brief accounts of C.D. attacks, &c., during the Great War, viz.:—W. Hartlepool (1914), The Dardanelles, Blocking Raids on Ostend and Zeebrugge, German Defences on the Belgian Coast, Capture of Tsing-tau and motor boat raids at Pola (1917) and Kronstadt (1919).

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The general conclusions which are drawn are based necessarily on much less data than in the case of Land Defences but the conclusion that a purely naval attack of a properly defended port is a hopeless proposition, will not be disputed until our unfortunate experiences in the Dardanelles (Nov. 1914-March, 1915) become blurred with time; when doubtless a few enthusiasts will revive once more this ancient and disastrous heresy. On the other hand it is laid down that while C.D. cannot prevent the naval bombardment of an area, the risk of serious results from a naval "area" bombardment is negligible, a conclusion which no one who saw the results of our constant coastal bombardments of the Belgian coast during the war will be inclined to dispute.

Development in Air Attack is said to be countered by development in Air Defences, and so far has progressed little beyond "area" bombardment. The question of the enemy use of gas is dealt with perforce in a "nebulous" way.

In discussing the general organisation of Defence Works the various responsibilities of the Navy, Army and Air Force are defined; the responsibility of the R.A.F. including close reconnaissance and co-operation with the R.A. It is difficult to believe that this allocation of responsibilities, so fraught with danger, will stand the test of time or that the last word has been said on the question of respective responsibilities.

Artillery armament is divided into "fixed and mobile" and the use of railway and transportable mountings is not contemplated for C.D. Great mechanical difficulties undoubtedly exist in connection with accuracy of fire, traversing, and stability, before guns on railway or transportable mountings can be used with efficiency in C.D., but the benefits which would accrue from a solution of these problems would be so great that it is a pity that experimental design to this end should be barred.

The question of siting batteries, the details of their requirements and Defence Electric Lights are dismissed in a few paragraphs, and the difficult problems of Defence against Aircraft and Signal communications are practically not dealt with, as little more than mention is made of these subjects; presumably future volumes of the *Manual of A.A. Defence* will deal fully with these points.

The book generally is significant not from what it says, but from what it does not say, and it is presumably a transitory publication intended to remind the Army that the whole subject has not been altogether lost sight of.

Efficient Land and Coast Defence (especially in the case of Great Britain) involves more than ever questions of time and space, and the closest co-operation between the Army and the Air Force, and in some measure the Navy also, for the earliest intelligence of hostile air-craft may often be obtained from sea-craft at a distance from our shores; efficient co-operation between different services is always a difficulty and is attained but rarely, judging from past history.

On shore the problems of co-operation between R.A., R.E., R.C. of S and R.A.F. are complex and require in each case much forethought and careful organisation. In fact sound organisation and signal communications must be the framework of any successful defence and the basis on which training is built up.

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Naval attack upon our coasts has become of minor importance, while the problems of attack by hostile air-craft have become a pressing urgency.

It is upon these problems that light is needed, and the laying down of a doctrine which will command the assent of informed opinion, and ensure (as far as is humanly possible) success in the day of trial.

H.B.

LA GUERRE EN ACTION. LE 22 AOÛT, 1914, AU IV. CORPS D'ARMEE, VIRTON.

By COMMANDANT A. GRASSET. (Paris: Berger-Levrault.) Price 10 francs.

This is the third of Commandant Grasset's most valuable and instructive studies of the opening fighting in August, 1914. The two earlier ones were concerned with the combats at Neufchâteau and Ethe. The actions he has described are quite different to those fought by the B.E.F. on the defensive at Mons and Le Cateau, or in pursuit at the Marne; for in each of them both French and Germans were advancing, ignorant of each other's presence. The tactical lessons are, therefore, of greatest interest, and the problems presented are well worth considering by those who have promotion examinations and manœuvres before them. There is much to be learnt from the mistakes and misadventures. At Neufchâteau two forces struck each other literally at right angles; at Ethe, a French advanced guard was caught in a village, which by its situation compelled the force to make a turn at right angles to its general line of advance. In Virton a German and a French division settled down for the night within striking distance, unknown to each other. The Germans, starting first, at mid-night, discovered the French, drew back a little and dug in; they easily dealt with the cavalry sent forward to get information in the morning mist, and then attacked.

Unfortunately, from our special point of view, there is not a word about the engineers, except that in one of the two advanced guards there was a small party; the French infantry of 1914 seem to have been capable of doing for themselves what battle engineering they required in the way of bridging and removing obstacles. One battalion, which, finding strong opposition, slipped into a churchyard and defended its walls, held its ground without difficulty and had hardly any losses; but elsewhere the infantry, thanks to "doctrine," showed a distinct disinclination to entrench, and suffered accordingly.

Commandant Grasset tells his story most vividly, and provides a large number of situation maps, so the course of the fighting is very easy to follow. As he gives the information at the disposal of the divisional and corps commanders, there is ample material to work out how the C.R.E. of a British division in like circumstances might have advised his general, and how the field companies might have been employed in aid of the infantry, while as pure military history the book is in the very first class.

J.E.E.

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LUDENDORFF SUR LE FRONT RUSSE, 1914-1915.

By GENERAL CAMON. (Berger Levrault. 1925). Price 6.75 fr.

This is the second book produced by General Camon this year. It consists of articles which have already appeared in the *Revue Militaire Générale*. The book is based mainly on the published accounts of Hindenburg, Ludendorff, and Falkenhayn, and includes many quotations from their works substantiating the author's ideas. No official documents on the period, either German or Russian, are yet available.

The author explains in his preface the object of his study of Ludendorff's methods. It is briefly this. Ludendorff appears to have conceived all his manœuvres with a view to bringing about the "manœuvre napoléonienne," i.e., "la manœuvre sur les derrières de l'adversaire"; whereas for actual battle he showed a preference for the "schèma de Cannes." The study of Ludendorff's methods is not merely of historical interest: the author considers that the German leader is still young enough to take part in the future war of revenge that he imagines Germany to be already preparing. In addition, all budding German strategists are now busily engaged in studying his methods and battles.

General Camon somewhat naively adds that he had invented these "schèmas" before the war, basing his nomenclature on Napoleon's own expressions. To the fact that the *École de Guerre* refused to have anything to do with his ideas in pre-war days, he largely attributes France's lack of success in the late war!

The constant repetition of the phrases "la manœuvre napoléonienne" and "le schèma de Cannes," gives the reader the idea that these are the only methods of conducting war. How simple it would all be if this were so!

To supplement his two main ideas the author has invented a series of "catch-words"; e.g., "Masse de démonstration," "Masse de choc" or "de rupture," "Masse de manœuvre," etc. These or similar expressions appear again and again in describing various battles, and give the reader that same uncomfortable feeling that is produced by reading the jargon found in the works of certain modern English military writers. Owing to the annoying effect of the author's phraseology the book requires a considerable effort to read.

The book, however, is well worth the effort, throwing as it does a most interesting light on Ludendorff's strategy and methods. The sub-title "Manœuvres et Batailles" gives the clue to the arrangement of the book. It is divided into two parts; the first a description of various manœuvres, including Lodz (Nov., 1914), Bialystok (Feb., 1915), and Vilna (Sept., 1915); the second a brief description of four battles from Tannenburg to Augustowo. In the case of Lodz the preliminary operations described in Part I., are followed by an account of the battle in Part II.

The author's main conclusion is that whereas in his preliminary operations Ludendorff always endeavoured to bring off his results by the manœuvre napoléonienne," when it came to a pitched battle he preferred

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the "schèma de Cannes." The modern conception of the former, he says, is the wide turning movement by a powerful and mobile force launched against the enemy communications at a considerable distance in his rear, followed up by a strong frontal or flank attack against the enemy, already threatened with lack of supplies, etc., by the movement against his L. of C.

In July, 1915, Ludendorff proposed a movement on Vilna on these lines, similar to the operations of Napoleon himself at the same place 100 years previously. Falkenhayn, however, refused to take the risks involved. In September, 1915, Falkenhayn, having been recalled to the Western front, Ludendorff undertook the operation. Unfortunately for him, he had fewer troops available than in July, and by September the Russian right wing had been withdrawn considerably. The result was that the German forces were insufficient to achieve a dramatic success, and the Russians escaped with the loss of a large area of country.

The second part of the book deals with the conception of Cannae as applied by Ludendorff. General Camon first shows in a few short but interesting descriptions, how the idea of envelopment on both flanks, as demonstrated by Hannibal at Cannae, was modified with success by Frederick II. at Leuthen and later by Napoleon ("la manœuvre napoléonienne"). He then shows how and why Moltke went back to the enveloping idea, quoting his use of three main armies both in 1866 and in 1870. The same idea was taught by Schlieffen during the 15 years he was Chief of the Great General Staff. Finally, we have an account of how Ludendorff applied the idea in two definite battles, namely, Tannenburg and Augustowo, and of how, at Insterburg, he reverted to the Napoleonic idea.

That Ludendorff applied Napoleon's ideas, but did not always follow his methods, was shown at the battle of Lodz. There, the direction of the actual battle was left by Ludendorff in Mackensen's hands, this being in accordance with established German custom. Mackensen himself lived much too far from the scene of action to exercise any real control. In criticising this action of Ludendorff, General Camon quotes Napoleon, writing from Vilna, July 6th, 1812, giving certain instructions to Murat, the Emperor concluded: *Mais mon intention n'est point qu'on engage une aussi grande affaire sans ma présence.*

In summing up, General Camon points out that, under modern conditions and with equally well trained armies, the larger the forces engaged, the less chance there is of successful encirclement. He reminds us that had the Russian leadership and equipment been less unequal to that of the Germans, the results of these two battles would have been very different. He concludes with a plea for the study of "le schèma napoléonien," the excellence of which he says is "incontestable."

The volume contains a number of indifferent sketches, for the majority of which a reading glass is essential.

G.E.G.

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LE 8e CORPS EN LORRAINE, AOUT-OCTOBRE, 1914.

By General De Castelli. (Berger-Levrault.) 12 fr.

General De Castelli was in command of the 8th French Corps during the first two months of the Great War, and his book deals with a period of strenuous fighting, which probably deserves more study than it receives on this side of the English Channel. The period divides itself into four fairly distinct phases as far as the 8th Corps was concerned, namely:—

1. The disastrous advance into German Lorraine of August, 1914, culminating in the defeat of the French at Saarburg.
2. The defence of the "Trouée de Charmes" between Toul and Epinal.
3. The period of the German advance south of Verdun which resulted in the formation of the St. Mihiel salient.
4. The fighting in the Forêt d'Apremont, east of St. Mihiel, which ended in the establishment of trench warfare early in October.

The 8th Corps played a prominent part in these operations, especially as it was situated on the outbreak of war on the extreme left of the First Army, and became involved to a considerable extent in the operations of the Second Army. During the German attacks which penetrated to St. Mihiel, however, the Corps was withdrawn from the line (on September 19th) under orders from G.Q.G. and spent several days in moving backwards and forwards without ever coming into action as a complete Corps. It was not till the end of the month that the Corps Commander found all his troops again under his orders, in the Forêt d'Apremont sector. It is to this withdrawal, which was carried out as one of the divisions of the Corps was engaged in a successful counter-attack, that General de Castelli attributes the German success on this part of the front.

In spite of the importance of the operations described, the book suffers from two great drawbacks, at any rate to the English reader. One is that there are no maps or sketches, merely a reference to some dozen 1/80,000 or 1/200,000 French maps being given. As the operations are described in considerable detail, to read the book without the maps is to lose the greater part of its value, while they are not easy to obtain. The second drawback is that, although the book is ostensibly written to draw attention to the importance of the success of the French armies in preventing a German break-through on this part of the Western Front, it consists largely of a vindication of the actions and opinions of the author, who was relieved of his command on October 10th as being "too worn out by the strain of operations to be able to continue to carry out his duties as a commander." General de Castelli claims that the real reason was continued differences of opinion with the First Army Commander, and especially his opposition to the policy of carrying out a long series of attacks against strong positions, which merely resulted in unnecessary loss of life. One naturally calls to mind General de Lanrezac's "Plan de Campagne Française," but General de Castelli is unable to quote extracts from orders and documents, with the exception of war diaries, which are only narratives of events. This places him at a disadvantage, compared to General de Lanrezac; in addition,

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his method of writing in the third person is unattractive. There is no doubt that the stubborn resistance of the French on the eastern portion of the battle front, in which the 8th Corps took a leading part, contributed largely to the success of the manœuvre of the Marne; and it is understandable that General de Castelli does not wish the part played by his Corps to be forgotten. The description, however, of the friction between corps and army headquarters is not very pleasant reading; in one place the author even speaks of the "reign of terror" which held sway throughout the First Army!

In conclusion, the general impression given by the book is that it is well worth reading by any one who wishes to understand and appreciate the somewhat involved, but none the less important, fighting which took place in Lorraine during the early months of the Great War; but such study is of little value unless the requisite maps are obtainable. On the other hand, although many of the author's criticisms of the Higher Command are evidently well-founded, the spirit of controversy pervading the entire book is liable to detract from its merits as a detailed description of operations.

H.A.J.P.

COURS DE CRYPTOGRAPHIE.

By Colonel M. Givierge. (Berger-Levrault.) 20 fr.

This book is written not for experts, but for enquirers, although any one who reads and masters it will need only experience to make him an expert, so clearly are the various problems set out.

We had hoped that the book might contain some sensational revelations of important messages decoded during the Great War, but the author contents himself with mention of only two examples, and one of these was probably not a deciphering from first principles, but a commercial transaction. He states that Ludendorff had the Russian cipher at Tannenburg, and as the Russians used W/T entirely between armies, he was always well informed of the Russian plans. The other example is German W/T messages at the Marne, which were deciphered by the French—but only some weeks after the battle! The latter example is probably a useful warning to budding "decipherers."

The author divides ciphers into three main systems:—

1. Substitution systems.
2. Transposition systems.
3. Dictionaries or codes.

Of these, substitution ciphers probably offer the easiest lines of attack, along the lines of frequencies of recurrence of single letters, pairs, and even groups of letters. Tables of such frequencies, in many languages, are obtainable.

Transposition systems, *i.e.*, systems in which a "salad" is made of the letters or words of the text, according to some pre-arranged system, must again be attacked by examination of frequencies, this time of pairs of letters, with the primary object of discovering the "tableau" in which the text is written for enciphering. As this may be of any number of letters either way, across or down, and either complete (*i.e.*, gaps

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filled with dummies) or incomplete, it is obvious that the problem is no easy one. In fact, given only short messages to work on, the anagram method of simple trial and error may be the only possible way.

Whatever method is adopted, the author strongly recommends the student "to try something, and not sit for whole days looking at the problem!" However, to give him his dues, he suggests many methods of trial.

In the chapter on dictionaries and codes a description of the various commercial codes in use is given, but the author emphasises that in war a specially prepared book-code will probably be used, and here the decipherer alone is powerless. Other branches of the intelligence system must help, *i.e.*, steal the book.

The author concludes with an interesting chapter on ciphering machines. The fact that the War Office are inviting inventions of such machines through the Daily Press reminds one of the prominence that ciphering and deciphering are likely to have in war in these days of universal wireless. Any prospective inventor of a ciphering machine would do well to read this book, if only to discover what is wanted, and what to avoid.

W E.B

THE THEORY OF MEASUREMENTS.

By LUCIUS TUTTLE, B.A.(Yale), M.D. (John Hopkins), formerly Associate in Physics, Jefferson Medical College, Philadelphia, and JOHN SATTERLY, M.A. (Cambridge), D.Sc., London, A.R.Sc. (London), F.P.S.L., F.R.C.S., Professor of Physics, University of Toronto. (Longmans Green & Co.) Price 12/6.

Recognising that absolute accuracy of observation is unattainable, the authors have sought to give full and clear information as to the scientific recording of measurements and observations, their classification, reduction, etc., so as to secure a maximum of accuracy with a minimum of labour. Quite a third of the treatise is very elementary, dealing with weights and measures, abridged arithmetic, angles, circular measure, Vernier scales, logarithms, significant figures, small magnitudes, graphical representation, etc., but a considerable part of the elementary portion is well worthy of attention, there is many a useful tip, and a grasp of the admirable chapters on significant figures will save the student much needless arithmetical labour in the future. The more advanced part of the treatise deals, *inter alia*, with the following subjects:—interpolation, extrapolation, relative errors, uncertain figures, superfluous accuracy, possible and probable errors. Harmony and disagreement of observations, classification of errors, deviation and dispersion, the weighting of observations, the rejection of doubtful observations, indirect observations, the method of least squares, the slide rule, the representation of statistics

A fair idea of the scope of the work will be given if I quote a couple of examples. (1) If (t) seconds is the record time of a trotting race of (m) miles, find the relation between (m) and (t) from the following data:—

(t)	119,	257,	416,	598,	etc.
(m)	1,	2,	3,	4,	etc.

(2) The magnet of a magnetometer was set in vibration and the time

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of passage through the centre was taken with a half-seconds chronometer; the time of passage through the centre was taken, with the following results; here follows a very elaborate table. Find the time of vibration.

In this case, of course, every observation would have to be "weighted."

The arrangement might possibly have been improved, for example, the subject of errors has been dealt with in three different chapters.

The term "observations" instead of "measurements" in the title would give English students a better idea of the scope of the work.

The treatise is full of useful information ably and clearly expounded, and should appeal to everyone responsible for observational work and to actuaries.

The examples are numerous and well chosen.

J. M. WADE, *Lt.-Col.*, B.Sc., London.

BATS, MOSQUITOES AND DOLLARS.

By DR. CHARLES A. R. CAMPBELL, M.D. (The Stratford Company, Boston, Massachusetts.) Price $3.

No apology is needed to readers of this Journal for calling their attention to a book dealing with the extermination of mosquitoes. The Corps has borne its share in the war for many years now and the results upon the health of our garrisons in tropical stations have been surprising. In this book Dr. Campbell, of St. Antonio, Texas, tells the tale of his research and experiments by which he has discovered that bats, the chief enemies of night-flying mosquitoes, can be cultivated like bees in hives or "roosts" and located in the neighbourhood of mosquito swamps. The experiments lasted over many years, but ended in complete success. The installation of a bat-roost will eliminate the danger of infection from mosquitoes in the most malarious area, and incidentally from the droppings of the bats, mainly consisting of the undigested fragments of mosquito bodies, is obtained a most valuable guano which commands a high price as a manure. The story is full of interest and well told. The first roost was a costly failure. Dr. Campbell "suspended his professional career, closed his office, and left family and friends for the mountainous wilds of his beloved State (Texas) with a firm resolution not to return without a complete knowledge and solution of the great problem." He found it, and his new roost "built according to the new plans, scented with a quantity of an especially prepared guano which carries a sexual odor," has been a brilliant success. All honour is due to this indefatigable explorer for his invaluable discovery. He mentions other roosts which have now been erected in America and one in Italy, and gives the cost of a bat roost at between 500 and 700 dollars. The plan and the special guano are no doubt secrets.

The enemy of the day-flying mosquito is the dragon fly. Dr. Campbell has much to tell us about dragon flies, but he leaves the solution of the problem of their cultivation to others. One experiment of his is instructive. He found that the oiling of a pool in which both mosquitoes and dragon flies were breeding was successful in driving away the dragon flies, but not the mosquitoes. After about eight days the mosquitoes had returned and soon rendered the neighbourhood uninhabitable.

F.E.G.S.

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MOTOR MANUALS. VOL. III.: THE MECHANISM OF THE CAR.

By Arthur W. Judge. (Chapman and Hall.) Price 4s.

The two previous volumes of this series have already been reviewed. The subject matter in Vol. III. is presented to the reader in the same manner as the preceding volumes, namely, the basic principles of various mechanisms, etc., embodied in motor cars are first discussed and explained in as non-technical language as possible, and these principles are afterwards illustrated by actual examples taken from the latest automobile practice.

The first two volumes of this series dealt with the engine and carburettor. Volume III. deals with the chassis, frame and suspension systems, front axle and steering, clutch, gear-box, propeller shaft, back axle and brakes. There is a chapter on alternative transmission systems, in which friction, hydraulic, and two forms of electric transmission are described, together with Constantinesco and De Lavaud variable transmission systems.

There are chapters on brakes, traction, and braking principles. The former has a good deal of space devoted to the description of the four-wheel brake. The latter has some interesting formulæ on power, adhesion of wheels and braking, engine revolutions, car speed, etc. Two types of steam car, one electric car, and one semi-tracked vehicle are discussed.

This is a most useful volume. It is well illustrated, the descriptions are clear, and the subject matter carefully chosen.

G.C.G.

SINGAPORE AND NAVAL GEOGRAPHY.

By Vaughan Cornish, D.Sc., F.R.G.S. (Paper covered pamphlet, 16-in. by 16in., published by Sifton Praed.) Price 5s.

In this reprint of a paper read at a meeting of the Royal Colonial Institute in June, 1925, Dr. Vaughan Cornish gives a short review of the naval and strategical considerations which demand the construction of a fully equipped Naval dockyard at Singapore. The paper takes a wide view of the problem, and is illustrated by an excellent series of maps designed to convey a truer impression of the ocean communications of the world than is obtainable from the usual atlases. The question of the Singapore base is a vital one in the problem of Imperial Defence, and Dr. Cornish has stated the main issues very clearly.

R.H.D.

IMPERIAL MILITARY GEOGRAPHY.

By Capt. D. H. Cole, M.B.E., F.R.G.S., *A.E.C.* Third edition. (Sifton Praed.) Price 10/-

This valuable book, first published in January, 1924, has already been through two editions and a reprint. In this, the third edition, the author has seized the opportunity to include much new material and revise the existing information. A chapter has been added on Climates of the

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Empire, and special stress is laid on matters concerning Imperial Defence. A new section dealing with the "Heart of the Empire" has been added, and extra paragraphs dealing with the fighting races of Africa, and the States of modern Arabia inserted. The chapter on Cables and Wireless has been revised and brought up to date. Seven new diagrams and eight maps, including sketch maps of the British Isles, Canada, and the Indian Railway systems, are provided.

The new edition is thus a great improvement on an already very valuable work, and the price remains the same.

R.P.P.-W.

MAGAZINES.

REVUE MILITAIRE FRANCAISE.

(*June*, 1925.)—*Is Germany moving towards a Militia Army?* By C. When the question is asked "How is it that our late enemy has succeeded in breaking through the meshes of the net by which the framers of the Treaty of Versailles thought to cripple her army?" the answer frequently received is, "By adopting the militia system." Taking as the definition of a militia system that given by M. Jaurés in *L'Armée Nouvelle*, the writer shows that in no single instance are the conditions fulfilled in the German organisation, which is a carefully devised instrument for maintaining the system and traditions of the old army, with such improvements as the experiences of the late war have shown to be necessary. An article worthy of perusal.

French and German Fortifications. The conclusion of Col. Normand's article. After studying the part played by the various fortresses during the late war, and most of them contributed a greater or less degree of assistance to their own side, Col. Normand proceeds to sum up his conclusions. His arguments in favour of well-devised schemes of permanent fortification are well marshalled, and he brings out their superiority to field defences, whilst the value of the latter as adjuncts to the former and in the open field are not lost sight of. An interesting and instructive article.

An Encounter Battle, Virton. The continuation of Commandant Grasset's article, describing the capture of Meix, N.W. of Virton, by the French, and their preparations for an attack on Robelmont, which had unfortunately to be abandoned owing to an alarm, later proved to be false, that a German force was threatening their left. The artillery, however, had retired and could not re-occupy their position in the dusk. Between this and Virton the French also achieved a success, capturing the German first line trenches, the elaborate nature of which caused great surprise. The assault was not ordered by any high authority, and appears to have been a spontaneous effort on the part of the three battered and almost exhausted regiments there in line, showing the extent to which they were impregnated with the doctrine of the attack. The article is accompanied by a sketch of the position at 18.00 hours, and by a copy of

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the Belgian 1/40,000 map showing the general position at midnight on 22/23 August. The Corps Commander's orders for 23rd, issued at 23.30 on 22nd, are given in full. At that hour he had received no orders from Army H.Q. (*To be continued*).

The British Empire in 1924. The conclusion of Commandant Texier's article—Part II. The imperial policy of the Labour Cabinet. After a summary account of the development of the British Empire, and of the recent relations between the Mother Country and the Dependencies and India, the writer studies the effect on these relations of the advent to office of a Labour Government. His account is fairly impartial, and if some of his deductions from history may be open to challenge, he has evidently been reading H. G. Wells' version, a quotation from which is made. His conclusion is that the measures of "disimperialization," of which the Macdonald Cabinet may be accused, have been compensated by the firm decisions taken in all circumstances in which the vital interests of the Empire were concerned. Singapore and Imperial Preference are evidently not considered vital, for he proceeds to say that nothing of the power and unity of the Empire has been lost by the advent to power (*sic*) of pacifist and anti-imperial sentiments.

The Battle of the Marne. Was it commenced a Day too soon? By Robert Duché. In an article in the *Temps* of 22nd December, 1922, General Mallaterre argues that circumstances imposed the 6th September, 1914, for joining battle, and that if the French VIth Army had waited till next day it would have been opposed not only by the German 4th Reserve Corps, but by the 2nd and 4th Active Corps, which von Kluck caused to withdraw to the north during the 6th, not to parry the unexpected attack of the VIth Army, but to conform to imperative orders from the Great General Staff. In this article are studied the events immediately preceding the battle so that a correct conclusion may be derived. In Chapter I the orders and messages received by von Kluck and his orders issued thereon from 4th to 6th September are examined at some length, and the conclusion arrived at is that von Kluck was so far obsessed by his determination to be the general who would turn the Allied left that neither orders from G.H.Q. nor reports from neighbouring formations of a powerful French concentration on his right, could induce him definitely to dispose his army as a flank guard. It was only after his 4th Reserve Corps had been attacked on the afternoon of the 5th that he ordered the 2nd and 4th Corps to retire at all, and only after he had heard that the 4th Reserve Corps had been forced to retreat that he directed the other two Corps to proceed north of the Marne on 6th. The article is illustrated by a diagram. (*To be continued*).

The Decline of the German Effectives. The German offensives on the Aisne (27th May) and Oise (9th June, 1918) are dealt with this month. (*To be continued*).

Foreign Military News. Switzerland. The new Army Organization Act came into operation on 1st July. The principal changes are the replacement in all battalions of the fourth company by a machine-gun company, and the formation of a new regiment of mountain infantry from three already existing battalions. In the cavalry, guides are suppressed and the 4th Brigade disappears. In the artillery, 25 tractor

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batteries of fortress guns are to be formed, and in aviation, all the squadrons are grouped into 30 companies.

Japan. Under the pressure of public opinion, effectives (officers and men) are being seriously reduced, and now number 195,000 only, a reduction of one-third from the strength in 1922. The reduction of four divisions would entail the elimination of 2,000 officers, but only 1,000 will be retired, owing to the creation of new air, tank, and A.A. units, and to the organization of preparatory military instruction.

(*July*, 1925.)—*The Battle of the Marne.* M. Robert Duché's article is concluded, continuing the narration of events on 7th September. The conclusions then drawn are (i) that it was only General Gallieni's attack on the German 4th Reserve Corps on 5th that induced von Kluck to take the half measures he did to strengthen his right flank guard, and (ii) that if this attack had not been made on 5th, the plan of the French G.H.Q. would have had time to mature. The 2nd and 4th German Corps on 5th and 6th would have advanced further to the south where they would have been inextricably gripped by the general frontal attack of the Allies. General Gallieni, reinforced by troops from the east and depôts, could then easily have brushed aside the weaker German force and advanced against the rear and communications of the German armies with decisive results. Besides, Gallieni's army had been placed with certain reservations under the orders of the C. in C. and should not have been seriously engaged without previous reference to him.

Concerning a German Opinion. Chap. V of this article is continued, and answers separately each of the von Taysen's criticisms of the French infantry. 1st—*The dogma of superiority of fire does not necessarily imply the subjection of the infantry to the other arms.* The fact that the formation commander arranges that, for as long a period as possible, infantry should have the support of guns, tanks, and aircraft where and when required, implies no subjection of the infantry except to himself. The French *Infantry Regulations* are, however, misleading in stating that only exceptionally will infantry have to fight without the assistance of the other arms; the possibility of their having to do so is ever present, and this faulty teaching requires rectification. At the same time infantry should be sufficiently powerfully armed to be able to act alone, and this will only be when they have their own accompanying artillery, and when the directly supporting artillery is more definitely placed under their orders. These remarks apply more especially to war of position, but are equally applicable to encounter battles where two forces meet face to face. The encounter battle where one wing of the enemy is to be surrounded or a gap in his lines exploited, is different. Here the element of surprise is all-important and discounts the rule regarding superiority of fire. The writers would like to see the principles of such a combat given a place of honour in the regulations, but it must be acknowledged that von Taysen is correct in saying that the present text is dumb in this respect. 2nd point.—*The dogma ought not to lead infantry to forget the value of manœuvres and the hand to hand conflict.* Once the enemy's position is entered, movement can only be carried out if the attack can develop superiority of fire. The regulations are therefore right in laying stress on the latter, but it would be an improvement if they also emphasized the

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value of the former. 3rd point.—*The dogma should not allure infantry into excessive care to avoid casualties.* The regulations certainly state that victory cannot be won without sacrifice of life, but perhaps err in referring to "a few losses which it is fantastic to hope entirely to avoid." If the soldier is not taught to realize that losses may at times be severe he may have a rude awakening after hostilities have been commenced and may lose his nerve. The effect of the regulations should be to galvanize his energies and promote in him a spirit of self-sacrifice. 4th point.—*The dogma should not result in excessive inflation of the so-called material arms at the expense of the infantry.* Whatever irresponsible individuals may say, it is unthinkable that the military authorities would ever increase the auxiliary at the expense of the acknowledged principal arm. (*To be continued*).

The Tank as an Economical Weapon. By Lt.-Col. Velpry. The writer deduces from the performances of the tanks in the late war that improved tanks will economise cost, material, time and loss of life in future wars. For an effectual artillery preparation, an expenditure of 1,500 to 3,000 tons of projectiles per kilometre of front is required, costing 12 to 24 millions of francs. About 20 tanks, costing 4 millions for light, or 7 millions for the heavy type, would produce the same or better effect, but, whereas the shells will have disappeared for ever, 90% of the light, or 60% of the heavy tanks would emerge unscathed and be available for a fresh advance more quickly than the guns could change position. Less material and less factory labour would be required for the tanks, less transport to bring them to site, the loss of life during the enemy's counter-preparation would be avoided, and advance through the position under cover of tanks is less costly than when artillery alone is employed. But the existing tank is too vulnerable to machine and anti-tank gun fire. A really heavy tank is required, protected by 25 c.m. of armour and carrying 3 or 4 guns, which could only be effectively engaged by a 25 c.m. gun moved on caterpillar tracks by motor power, but which, carrying no light armament for its own defence would fall an easy prey to its opponent. The financial effort demanded to produce such tanks would be well expended in view of the decreasing French birthrate and growing paucity of recruits.

A Second Lesson of the American War of Secession. Lt.-Col. Daille in this article proposes to show that Grant's operations, after he became C. in C. of the Federal armies in March, 1864, afford a striking example of the methods which nations enjoying a superiority of force employ to defeat their adversaries. He commences with a statement of the general political and military situation of the Union early in 1864, and of the steps taken by Grant to reorganize and discipline his forces. He then traces the operations in Virginia up to the battle of the Wilderness, and illustrates his article by a sketch. (*To be continued*).

The Decline of the German Effectives in 1918. Lt.-Col. Paquet's article is continued and deals with the German offensive in Champagne on 15th July. (*To be continued*).

A German Controversy. Commandant Martin makes a further contribution to this subject with the review of an article in *Wessen und Wehr*, by General Kraft von Dellmensingen, defending Crown Prince Rupert of

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Bavaria from accusations brought against him by General Wetzel. The last named accuses the Prince of having prematurely undertaken his offensive in Lorraine on 20th August, 1914, instead of continuing his retirement with the view of drawing the French into a pocket, as planned by the German G.Q.G. so that it could be overwhelmed by von Schlieffen's favourite "Battle of Cannae" manœuvre. General von Dellmensingen quotes documents hitherto unpublished, particularly part of the German G.Q.G. instructions for the strategic deployment for the preliminary operations, and attempts to prove that Prince Rupert neither disobeyed his orders nor acted prematurely.

Under *Foreign Military News* is mentioned a new German monthly magazine "Kriegskunst in Wort und Bild" (first issue October, 1924), which appeals to the junior ranks of the Reichswehr and members of associations interested in military education. Each number contains an article inculcating patriotism, such as the life of some well-known military leader, a study in the employment of small bodies of troops of the various arms, comprising (*a*) theory, and accompanied by tables, sketches and photographs, and (*b*) a tactical problem, the solution of which appears in the next issue, an article on foreign politics or history of frankly anti-French tendency, and lastly a picture calculated to warn the soldier against wine, women and cards, spies, cowardice, etc.

Books and Reviews. Les origines immédiates de la guerre (28th June —4th August, 1914). Pierre Renouvin (Costes). Written by a historian highly qualified for dealing with such a subject, a professor of the Sorbonne, this book claims to be entirely free from bias of any description—a claim which the reader will readily endorse.

BULLETIN BELGE DES SCIENCES MILITAIRE.

(1925, Nos. 7 and 8).—The story of the operations of the Belgian Army during the Great War, 1914-1918, is continued in the numbers of the *Bulletin* under notice; further events occurring on October 7 are recorded therein. A relative calm prevailed during the night of October 6-7 on the left bank of the Scheldt opposite Schoonaerde, where the Belgian 4th Division was entrenched with a view to preventing the passage of the river by the enemy; the units of this Division took advantage of the apparent inactivity of the Germans to repair and strengthen their defences, which had been knocked about a good deal on the previous day by the hostile artillery. In the meantime, the Germans had succeeded in collecting boats and other bridging material at De Distel (2,000 yards below stream from Schoonaerde). An autumn mist hung over the valley; the conditions for passing troops across the stream being favourable, the Germans quickly seized their opportunity. At daybreak of October 7 some of the units of the 37th Landwehr Brigade began to cross the river in boats; a raft was meanwhile constructed, and as soon as it was ready a flying bridge was established at De Distel, and utilised for transporting other units of the same Brigade to the left bank of the Scheldt. It was not until 6.40 that the Belgians became aware of what had taken place at De Distel; they thereupon made an attempt by means of artillery fire to dislodge the enemy troops which had crossed the river. However, owing

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to the difficulty caused by the dense mist in ranging the guns, their fire proved ineffective, and the enemy was, in consequence, able to proceed with the establishment of a bridge-head and also to consolidate his position. As the situation developed, General Michel (Commanding 4th Division), whose reserves were exhausted, sent a message to the Commander of the Belgian 6th Division calling for support; the latter at once complied with the request made to him. The reinforcements sent by the 6th Division were, however, unable to make any headway, as the enemy had by now succeeded in making good his position on the northern bank. Soon after noon a counter-attack was launched by the Belgians, but before the troops detailed for this task came into collision with the Germans, they were called off and ordered to retire. By nightfall small parties of Germans had penetrated as far as Berlaere and Vankryk—about 2,000 yards N. of Schoonaerde—but the main body had been obliged to entrench itself on the line Daal—Overheet—about 1,000 yards N. of the river bank; the Belgians remained in contact with the enemy's advanced troops in this locality throughout the night of October 7-8. Other developments quickly followed. The Belgian G.H.Q. was now established at St. Nicolas; the view taken there was that the Belgian troops were extended on too wide a front to drive the Germans back to the right bank of the Scheldt and that even the shortest delay of the Field Army in its westward march might seriously compromise the safety of the whole, or at least a very considerable part of it. The German pressure in the neighbourhood of Ghent was increasing hourly—it had been reported that several skirmishes had already taken place between German cavalry and cyclists and Belgian volunteers, civic guards and gendarmes in that locality. A telegram handed in at 11.30 a.m. at Zeebrugge, announcing that a British force of about 15,000 men with horse, field and howitzer batteries (i.e., the 7th Division) had arrived and was being disembarked, did not reach the Belgian G.H.Q. at St. Nicolas until 5 p.m. By the afternoon of October 7 Capper's Division had concentrated near Bruges—the general situation on the Western Front, as known at the Belgian G.H.Q. at this time, is set out in the original article. General von Werder, who had been given command of the left wing of the besieging force, with a view to reinforcing the German troops which were held up near Berlaere, pushed on the construction of temporary bridges over the Scheldt; good progress was made, and by daybreak of October 8 he succeeded in transferring the whole of the 37th Landwehr Brigade and also the 1st Bavarian Landwehr Brigade to the left bank of the river. In the meantime, the *pionniers pontonniers cyclistes* of the Belgian Cavalry Division, during October 7, destroyed the iron swing-bridges (over the Scheldt) at Melle and Heusden with tonite, and also took the necessary steps to extend the inundations, begun on September 29, to the region comprising Calcken, Uytbergen and Overmeire (an area of about 1,250 acres). Further, an officer of the unit proceeded in an armoured motor car to Wichelen, where a large quantity of timber, which the enemy would, no doubt, have wished to seize for bridging purposes, was stored; he managed to set fire to and destroy all this material. The same officer made an attempt to effect the destruction of the temporary bridge thrown across the river by the enemy at Schoonaerde by floating

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a fire-boat on to it on the ebb-tide; contrary winds, however, drove his bark on to the river bank and he had finally to abandon the attempt. According to the author it was the "abstention persistante des autorités britanniques" to occupy Ghent which caused the Belgian High Command to give up the idea of making a stand on the line of the Scheldt with the Belgian Field Army. About noon on October 7 King Albert, at an audience, personally gave an express order, as a final instruction to General Deguise, the Governor of Antwerp, directing him to hold out to the bitter end; the King then proceeded to St. Nicolas, where the Belgian G.H.Q. was established. The Belgian 2nd Division had been placed at the disposal of General Deguise, and its Commander, according to his instructions, now took over the command of the "Second Line" of defence. The permanent works of this Line and their garrisons, however, still remained under the direct orders of the Governor of Antwerp. It is stated that the forts of the "Second Line" were not in a condition to meet any serious attack, and that this fact had been known for some time prior to the outbreak of hostilities by the Belgian Government and Parliament. Nevertheless, steps were taken to occupy this Line. Under direct instructions from the Governor, measures were set on foot on October 7 by the *compagnie de torpilleurs* to prepare the bridges of boats at the Tête de Flandres and Burght for destruction. On the same day the "compagnie de pontonniers" were ordered to dismantle the pontoon bridges at Rupelmonde and Hemixen and to destroy the permanent shore bays—these were of iron construction—at these places. The Governor had no mobile troops at his disposal for carrying out reconnaissances, and, in consequence, made enquiries as to the whereabouts of any airmen who might be available for this duty. He learnt that the Belgian High Command had moved the headquarters of the Air Force to Ostend, and that the squadrons of this Force which had been collected at Ghent, considering themselves to be in too exposed a position there, had also retired to Ostend. In their attack on Antwerp the Germans decided to husband their infantry, and to prepare the way for an advance carefully by artillery; consequently, as they still had a few field guns only on the north bank of the Nethe, the infantry was moved forward with the greatest caution. In order to provide for the close support of the infantry by the guns, light and heavy, bridging operations were actively pushed on by the engineers with the besieging force. During the night of October 7-8 the German preparations were sufficiently advanced, and the bombardment of Antwerp was begun, the central parts of the city, its southern suburbs and the old ramparts all receiving their share of attention from the German gunners.

Major B. E. M. Hierman contributes an article entitled *La problème des communications. Son influence sur l'organisation du génie*, to the numbers of the *Bulletin* under notice. Owing to the systematic destruction of roads and bridges carried out during the Great War, questions relating to the repair of the former and of the construction and re-construction of heavy types of temporary bridges, suitable for carrying mechanical transport and heavy artillery, now loom large as war-time engineering problems. To meet a situation in relation to "communications" similar to that which came into existence during the Great War,

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the Commanders of the Engineers with the various formations will naturally require an ample supply of suitable material, and a sufficient body of specialised troops to enable them efficiently to carry out their duties, including road repairs and the construction of heavy bridges. To secure this end Major Hierman puts forward certain proposals as to the numbers of units necessary as Divisional Engineers, Corps Engineers and Army Engineers, and the materials and equipment which should be provided for them in the Engineer Parks.

W.A.J.O'M.

MILITÄRWISSENSCHAFTLICHE UND TECHNISCHE MITTEILUNGEN.

(*July-August.*)—*Moltke or Schlieffen?* An article by Heinz Zatschek, which does not attempt to come to any conclusions, but by putting the affair of the Belgian Invasion in a new light, to reopen the discussion. It is a clear exposition of the strategical considerations which brought about the changes of plan. Little evidence is available as to Moltke's views, but it is certain he would have wished to avoid the invasion of Belgium in 1914; perhaps to draw the French forces into Lorraine, defeat them, and by following quickly on their heels, to overrun the fortified line. (To be continued.)

The Second Investment of Przemysl. Continuing from the last number Major Stuckheil relates the failure of the sortie. After two days' fighting the position was evidently hopeless, and the general retreat within the fortress ordered. Summing up, the author attributes the failure to (1) Too stereotyped a form of attack, (2) Impossibility of effecting surprise, (3) Good espionage work by the Russians, but also treachery in the garrison, coupled with general indiscretion of the Austro-Hungarian officers, and leakage of news transmitted by wireless, (4) The fact of the bad morale of the garrison at this time, and (5) Bad equipment.

The Second Tactics Problem is set in this number.

Considerations as to the Necessity of Cavalry. By Colonel Friedrich Kubin.—The author considers Cavalry in view of the needs of the reduced Austrian Army, and concludes that "the horse remains the most economical and certain means of supplementing the individual mobility of the soldier." Each of the six squadrons of the Austrian Army is organised into three mounted troops, one M.G. troop (two guns), and one troop mounted sappers.

The Next Great War, by Capt. Liddell Hart, is begun.—It is translated in full, but no comments are made.

A composite Article, entitled "*A Review of Military Science.*"

1. *Politics and the Conduct of War.* By Major General Hugo Schäfer. — . . . . "The cloud of War had already been in the sky for many decades, general preparation was made for it. It was mere chance where, when, and by whom the stone was set rolling . . . . And if the whole of the facts are faced, one is bound to come to the conclusion that Germany

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was, politically, very poorly prepared for War, while the work of the Entente was masterly. . . . . In particular, Asquith's writings give one a frank and instructive insight. . . . . Britain allied herself against the growing might of Germany. . . . . Yet at the time of mobilisation, the Kaiser still hoped that Britain would remain neutral. Britain and her world-wide Empire . . . . was firmly and unitedly organised, not only politically, navally, and militarily, but also in its administration and economically. . . . ." This propaganda is followed by a catalogue of the chief War writers, and of the chief questions over which they fail to agree.

2. *Tactics.* By Col. Joseph Feichtmeier.—A lucid sketch of the changes brought about during the War in the tactics of offence and defence, particularly by the multiplication of M.G.s and the perfection of aeroplanes. "Tactics have changed from a one-dimensional to a three-dimensional art." The effect of the War was to draw a clear distinction between the troops which could bring a great weight of fire to bear on the enemy, and the troops who finally attacked him. In defence, masking and camouflage are more important than protection. The article contains little that is new.

3. *The Munitions of War.* By Colonel of Engineers Rudolf Huppert.—An interesting article shewing clearly the distinction between the aims and the achievements of modern experiment. For their defence against tanks, infantry must have some arm combining attacking power, great mobility and the maximum of invulnerability, in fact, practically a form of tank. In the matter of hand-grenades, and smoke-bombs, the ideal, at present unattainable, would be a mechanism which need not be released before throwing; it should detonate on impact, and at the same time "duds" should be harmless.

As for the means of traction for the Artillery, the author concludes that for the present horses are indispensible for all divisional artillery, but that the mobile reserve should be equipped with motor transport. The horse must be eliminated when possible, owing to the dangers of poison gas.

(*Sept.-Oct.*)—A large part of this number is devoted to the achievements of the ex-Chief of the General Staff, Field Marshal Conrad, who died on 25th August, 1925. Much of this is of more interest to Austrians than to Englishmen; as, for instance, the first article, which is the funeral address pronounced by the Austrian Minister for War.

The Second Article is "Field Marshal Conrad," by Major-General Hugo Kerchnawe, a eulogy pure and simple. It gives a sketch of his career, and mentions some of his more important military writings.

Of greater interest, and more judicial, is the article by the Prussian, Major-General Rudolf Borries, who shows great admiration for Conrad's genius, but was not blind to his faults. No situation could be so bad, that he could not find an ingenious solution, but his optimism, and the tasks he imposed on the troops were often excessive. He opposed the appointment of a Generalissimo for the Central Powers.

Lt.-Col. Rudolf Kiszling contributes "*Field Marshal Conrad's Strategic Plan against Russia.*" Conrad's idea was formulated in 1909. The two

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Armies of the left wing were to advance to the San-Dniester line, and at the same time were to be prepared against a possible enveloping move by the Russians. The Germans were to make a corresponding attack towards and over the Narew. The Allies were then to move eastwards, and together with the Austrian Right, to defeat the enemy centred on Rovno and Proskurow. Subsequently they were to be driven towards the Black Sea or Kiev. This was almost the only pre-War strategic plan which, in spite of checks, was realised in its entirety.

Major-General Steinitz contributes, "*Conrad and his Development of the Infantry.*" The infantry regulations of 1911 were the first to reject the close-formation theory, the chief credit for the change being Conrad's.

Field-Marshal Conrad's Memoirs. By Edmund Glaise-Horstenau. The author, who implies that he was intimate with Conrad, states that his memoirs are based entirely on documentary evidence, and that his object in writing them was to give an unbiassed account of events as they happened. The five volumes completed before his death occupy the period from the beginning of his Service to the end of December, 1914.

The War in the Dolomites. By Lt.-Col. Valentin Feurstein.—(3 maps). (The beginning of this article was published in the last number). The author has evidently a rather poor opinion of the Italians, and is eloquent in praise of the low-category (largely volunteer) troops, who took part in the fighting. Each sector of the front is considered in turn, firstly a brief explanation of the strategical considerations, followed by an account of the fighting. The whole gives a good impression of the prevailing conditions.

An article *The New English Vickers Tank*, is taken from the *Militarwochenblatt*, and supplemented by Captain Fritz Heigl. Details, for which the author cannot absolutely vouch, are given of the armour, road and cross-country speeds, armament, effective range, etc.

The Review of Military Science is continued. In an editorial note it is explained that under this heading, in addition to longer articles on the developments of Military Science, short extracts will be made from noteworthy articles in certain periodicals. A list of 72 periodicals follows. Britain is represented by *Flight*, *The Royal Artillery Journal*, and *The Royal Engineers Journal*.

1. *Tactics.* By Colonel Feichtmeier. On mountain warfare the author has no new ideas. In village fighting, the reserve of the defending side must be kept in hand, and the counter made so as to cut off the village by envelopment.

2. *Active Service.* By Colonel Buyer. Reconnaissances, Protection Communications, etc., are dealt with. There is nothing new in the article.

3. *Organisation.* 4. *War History.* 5. *Small Arms and Artillery.* 6. *Aircraft.* 7. *Science and Warfare.* 8. *Naval Affairs.* All these are dealt with only by notices of articles appearing in the 72 magazines mentioned. Under 7 is a notice of an article which appeared in *Science for All.* An invention is claimed by which a cloud two miles square was precipitated as rain in 3½ minutes by means of "shooting" electrically charged sand from an aeroplane. It is thought it can be adapted to use against artificial smoke-screens.

T.H.B.

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HEERESTECHNIK.

(*July, August and September* numbers.) The July number contains an official article "Equations of motion for Road and Cross-country Vehicles." Two examples are worked out, to find the power necessary for a motor vehicle to maintain a certain speed under certain conditions, and to find the maximum speed of a certain vehicle under a certain load. The article is not of particular interest.

Major Justrow, who contributed an article to *Heerestechnik*, of November, 1924, on Range, Muzzle Velocity, and Weight of Projectiles, and who was criticised for his assumptions, methods, and conclusions by General Rohne in *Artilleristische Monatsheften*, argues the case at length. Most of the article is of personal interest. He believes that 2,400 atmospheres will prove to be the limiting internal pressure for field guns, and that after that muzzle velocity can only be increased by lengthening the barrel.

Notes on the new *Field Fortifications Manual, Part* 1, are completed by Major Klingbeil. In the front line, protection must be limited to weather and splinter-proof shelters; deep dug-outs are man traps. Further back, dug-outs should be small, several small ones at minimum internal length of 8 metres are best. As obstacles against tanks, the following natural features are recommended: water at least one metre deep, marshes, steep banks (slope over 1 in 1, and at least two metres in height) and woods with close-growing strong trees. When an attack is held up, in open warfare, the troops, deployed in depth, dig themselves in; according to the tactical situation and to the direction of the whole line, unit commanders link up these rifle pits and M.G. emplacements to establish firing trenches; these are developed into strong points, and finally they are all linked up. In actual battle, the forward area becomes a mass of shell holes, and all repairs to trenches, except as they concern the safety of the individual soldier, are useless. In laying out trenches, arrangements must be made for systematic drainage.

The manual is clear as to the use of the sappers. "For definite jobs of longer or shorter duration, platoons or companies of sappers under their own leaders are put at the disposal of the commanders of units of the "principal arms." As a rule, sappers should not be employed as infantry. Immediately on completion of their job, they return to their units. It is emphasized that on the occasion of a successful break through, the sappers must be reassembled by units, and made available for duty as such. Sapper officers of all ranks make suggestions to the unit commanders for the disposition of their weapons, and for the preparation and execution of technical steps in the lay out of, and fighting for, field fortifications."

Small Arms Abroad.—A lecture delivered recently by Brig.-Gen. Thompson (U.S. Army), together with a German opinion, is published under this heading. In America, light M.G.s (Lewis Guns) are regarded as of more moral than concrete effect, and bursts of fire with them are restricted to ranges of less than 100 yards. The needs of the Army can be met either by simplifying the light M.G. or by inventing a self-loading rifle. The former could only be done by lowering the muzzle velocity, and so using a lighter barrel. According to the German opinion this is

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useless, since such a weapon would lose all the good points of the M.G. and retain all its defects.

The Importance of Petroleum.—Under this heading the oil-fields of the world are enumerated, and the question of possible substitutes is touched upon. There is nothing new in the article.

Contribution on the Question of the Formula for Taxation, by Mr. Stadie. The motor taxation question is discussed, and its influence on design. The conclusion is that motor spirit should be taxed. The article is interesting, as England and Germany have similar methods of assessment. Much of Mr. Stadie's information is drawn from British sources.

Ordnance Manuals and Drawings.—Under this heading is an article appealing for greater use of the official handbooks; also giving the recommendations (as to technical drawings) of a Committee appointed to standardize practices in German industry. These recommendations are given in full, and they will be adopted in the German Army. T.H.B.

REVUE DU GENIE.

(*July*, 1925).—*The Working of Quarries for the VIIth Army.* (Concluded).—A description of the working, from the beginning of 1917, of a quarry at Lauw (Alsace). In the lay-out the levels were so adjusted and the Decauville track was so sited that no manhandling of the stone was necessary and all the trucks moved round the tracks in the same direction. All the buildings were of reinforced concrete. Careful organisation enabled the price of the stone to be reduced from 7 fr. 50 to 5 fr. 25 per yard cube, despite the fact that the workmen were either soldiers or inefficient civilians. In the beginning of 1918 a compressor plant was installed in order to use Ingersoll Rand compressed air hammers, worked by three men each; the price of stone produced by them was 3½ per cent. less than that produced by hand. Dynamite or cheddite were used as explosives, charges used being about ½-lb. The holes for them were at least 1¼-in. The stones from the crusher were put into small trucks and either unloaded directly into railway wagons or into hoppers for loading lorries. Three crushers were installed. Two hundred and nine men were employed, and for the first year the average daily production was 275 tons; after 18 months it had reached 440 tons. A great effort was made, with some success, to increase production by means of bounties, the principle being that half the money gained by the decreased cost of production, due to the increased amount, should be distributed in bounties.

Lighting and Ventilation of Mine Galleries.—Chapter II.—Ventilation.—The basis on which to work is the amount of air necessary in any circumstance, velocity of the air currents and the lengths of gallery which need no ventilation. Natural draught ventilation should always be assisted by some artificial means, in case the air pressures get changed and reverse the flow of air. The two methods of artificial ventilation are the blowing system and the sucking system: the conditions under which each one of these is the better, or in which they can be combined, are discussed. The uses, and details of construction, of shafts and boreholes to promote a natural draught are elaborated. Information on fans comes under the following heads:—Methods of working, power (for electrical and

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mechanical fans), velocity of issuing air, delivery, angular velocity and static pressure produced by it. Many types of fan are described. An empirical rule for finding the horse power required for any lengths of pipe-line is to use ¾ h.p. for each 50 m. of line; for more than 50 metres provide coupled fans. This rule only holds up to 150 m.

Building of a Bridge at Pinterville (*Eure*) by a detachment of the 3rd Regiment of Engineers—15th-20th October, 1924. This pile bridge was to replace one demolished in 1918 and was to be capable of carrying 3-ton axle loads. The bridge was about 120 feet long and was supported by five piled piers 20 feet apart and two abutment piers also of piles. The width of the bridge was 13 feet; in each pier there were 7 piles and five in each abutment. The piles varied from 11 to 18 feet in length and were 7¾-ins. square, and were driven 7-ft. to 10-ft. into hard chalk. The detachment consisted of four officers and 123 other ranks. Work was carried on night and day in six-hour shifts in squads of 37 men, divided into three gangs; one of eleven men, woodworkers, one of 19 working the pile drivers and one of seven doing odd jobs. The pile driving took 50 hours for 45 piles, using one driver. The whole bridge took 120 hours, including 18 hours for a light footbridge. Twelve hours were lost owing to bad weather.

A work table and the necessary calculations are appended. All the calculations are carried out by using the appropriate formula from various books. J.E.G.McC.

(*August*).—*Les travaux d'adduction d'eau a Souéida* (*Syria*). A full description of the execution of a project for laying on water from a distance of nearly 20 kilometres to the French Military post at Suéida. 15 kilometres were in cement pipes made *in situ*, the remainder in iron. The daily average of personnel employed was 210 and the whole work was completed in a little over eight months.

All the characteristic impediments that are liable to occur under such conditions did occur, and were surmounted. The article contains many hints both as regards personnel, materials and organisation which would be of use to engineers under similar circumstances.

Étude sur L'Éclairage et la Ventilation des Galeries de Mines (*concluded*). The writer gives formulae for calculating the loss of pressure (and thence the power required to produce a definite quantity of air) due to varying sizes of piping, elbows, etc., and gives examples. Tables are appended of various blowers, and graphs for calculating the flow of air in straight pipes of varying sizes. Additional tables are included in connection with the previous article, showing the sizes of wire for various lengths of circuits for a given range of current and pressure drop.

The "Cordeau détonant" used in Czecho-Slovakia. Stated to be filled with fulminate of mercury and paraffin wax, to weigh 35 lbs. per 100 metres, perfectly uniform in quality, flexible and capable of forming joints or branches by binding. Its sensitivity is markedly increased at temperatures in excess of 50° C. It is detonated by the impact of a projectile at a velocity over 2,600 f.s. Prolonged immersion in water produces no ill effect. The fulminate is treated with paraffin wax, and, provided that the latter has not escaped, the *cordeau* can be ignited and will burn without detonation. The *cordeau* is stated to be of the same

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nature as was in use in the Austro-Hungarian Army. (This fuze, or a similar one, was tried at the S.M.E. in 1907 and subsequent years).

(*September*, 1925).—*The Exploitation of the Forests in Les Landes* 1916-18. Summarises the general organisation for provision of timber under the "Inspection Générale du Service des Bois" organised in 1917 which at the period of maximum output produced 42,700 and purchased 154,000 metres cube of timber of sorts. A description of the organisation for clear felling an area of 358 *hectares* in Les Landes, where one officer and some 300 other ranks were employed.

Furnaces for the Production of Charcoal. Describes several appliances exhibited at a competition recently held.

The Housing Problem. An appeal for the provision of married quarters for re-enlisted N.C.O's, claiming that the net cost, allowing for interest and amortisation, would not be more than 500 francs per annum per head.

Floating Bridges on the Rhine. Extract from a paper published in another periodical, enumerating the various floating bridges and describing a typical example.

The Passage of the Danube at Sistovo, 23-11-16. A translation, with illustrations, of a paper by an Austrian Officer, describing the preparation and execution of this passage. Preparations were begun on August 10th, a month before Roumania declared war. The force consisted of 3 divisions and was ferried over the river eventually under cover of a fog against a somewhat feeble opposition. A floating bridge 927 metres in length was commenced on 24-11-16 and finished in 24 hours. The article contains a full description of the assemblage of the equipment and the methods of preparation and particularly of concealment.

A Map Exercise on the crossing of a river and canal. Gives a general and special idea, orders to the divisional "commandant du génie," his instructions, appreciation and orders. H.G.K.W.

MILITÄR WOCHENBLATT.

15th March, 1924. The leading article of this issue deals with gas warfare. After referring to a recent article in *Heerestechnik* on the stage of the preparations for the future gas war which has been reached in various countries, so far as this has been made public, the article observes that it shows how feverishly in spite of the Washington Agreement the development of this weapon is being worked at on all sides. It then seeks to discover the lines along which the tendencies are moving, for in the last war the use of gas was only elementary. After proving to his own satisfaction that the French were the first to break the rules of the Hague Convention of 1899 regarding the use of poison gas, the writer refers to the American gas "Lewisite," which is now enabling the Americans to give the lead in this matter when formerly they were entirely dependent on the French. Incidentally he observes that 27% of the American casualties were due to the German gas. (In this connection it may not be out of place to recall a yarn of the war concerning the American gas mask, one criticism of which was to the effect that "the twine you wind round your belly is all right, but the rest's nowhere"!) As regards the Lewisite, which an exaggerated claim asserts to be so strong that a few drops on the hand are enough to kill a

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man, it is said that 150 tons of this had been prepared in November, '18, when the war came to an end. For safety's sake this was sunk at sea, but complete formulæ are preserved for its manufacture if necessary. It is considered most important to possess a mixture of gases, whereby by adding a "camouflage" gas the mixture is not remarked as poisonous —a gas without smell, with which, according to Belgian information, experiments are proceeding at Puteaux, near Paris. The ideal for many is a gas which works through the ears on a man's sense of balance, robbing him of his wits or even of consciousness. This is all the writer has to say about actual gases, observing that America is the only state to publish details of its poison gas, all other nations preserving silence about their activities.

As regards the use of gas in war, the writer then refers to various authorities, Belgian, French, American, English and Swiss, to support the contention that since the discovery of gunpowder nothing has tended to alter the conditions of warfare so much as gas, one of the four weapons of the future "war to a finish"—infantry, artillery, airmen and gas. Whereas in the last war primitive gas cylinders were first used, then projectors and gas shell, the question of bombing from aeroplanes has since been most to the fore. The writer then quotes Gen. Debeney to show that in the next war the use of gas bombs from aeroplanes will be so extended and far reaching as is hard to picture now. With regard to the defensive use of gas, the *Bulletin Belge* gives two examples from 1918, which are of interest in the study of the future use of gas; one was the German offensive in March, 1918, when "yellow cross" was used as flank protection to the attack, and the other the Kemmel offensive where mustard gas was discharged on the ground in front of the objectives reached, so as to protect the position won from counter attack, and also incidentally prevented, at first, any further advance of the attack.

Pursuing further this idea of protection by gas screens, one reaches the notion of laying down an impassable gas barrier in the no-man's-land between the two front lines, which would be more effective than any trenches, wire entanglements or similar devices of position warfare. And so on to yet more fantastic ideas.

Thus we see the use of poison gas in full development everywhere. Gas fantasies, "*rêves d'hier, hypothèses et projets d'aujourd'hui, réalités de demain.*"

And yet it is asked whether this weapon, the use of which was prohibited at Washington, had not better be dispensed with. But the reply is always: "No, impossible." So, says the English Captain Auld, one makes a step forward, and then, though it is a thousand times more cursed and pernicious, withdrawal is impossible.

In conclusion, the writer says the next war will be begun with the contestants "well provided with gas and poison-projectiles," and at the same time each will seek to prove to the world that it is the wicked enemy that must bear the responsibility for first using this terrible weapon.

E.G.W.

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CORRESPONDENCE.

BROKEN LINTELS.

To The Editor, *The Royal Engineers' Journal.*

DEAR SIR,

On page 516 of the September number of the *Royal Engineers' Journal* there is a reference to an article in the *Revue du Génie Militaire* for April, 1925, entitled "Notes on a Detail of Construction in the Roman Arenas at Arles and Nîmes." In both these structures certain stone lintels over the arcades running right round the arenas are nearly all fractured. The Romans were as a rule sound constructional architects and it is surprising to find such an example of faulty design.

The present writer visited both places at Whitsuntide, 1923. At Arles the building was not carefully examined as attention was chiefly given to a mild entertainment with bulls which was in progress and the arena was packed with people. It may be mentioned that the show involved no danger to the bulls, which were turned into the arena with bunches of ribbons on their horns. The sporting youths of Arles went into the ring and a prize was given to the first to get the ribbons off, a somewhat risky performance. There was, however, not much excitement except when on two occasions the bull jumped the barricade round the arena and landed amongst the people.

At Nîmes, however, the writer and a small party were escorted by M. Emile Espérandieu, who is the curator of the Roman buildings in the town, including besides the arena, the famous Maison Carrée and many others, so that there was every opportunity for examining the building carefully. The fractured lintels were very conspicuous, especially as they had been repaired with iron cramps.

These Roman failures having been noted, attention is now invited to an almost precisely similar case in quite another part of the world. In the journal for December, 1924, there is an extemely interesting article by Colonel C. W. Davy, C.M.G., on the famous ruins of Angkor, in Cambodia, dating from about the twelfth century. On page 622 there is a sketch of a broken lintel which might almost pass for Nimes, the chief difference being that the galleries there and at Arles face inwards towards the arena, and at Angkor they, apparently, run round the outside of the buildings. The present writer made a sketch at Nîmes showing the failure, but this has, unfortunately, been mislaid.

In Fergusson's *History of Indian and Eastern Architecture*, there is a description of the Angkor buildings, called by him Nakhon Wat, and he gives a cross section similar to Colonel Davy's referred to above but he says nothing about a structural failure. It is probable that Fergusson had not visited Angkor personally. No fracture is shown in his section. His book was published in 1876, and at that time the illustrations were all engravings from photographs, excepting of course, cross sections and plans of buildings. He does not say how he obtained this particular section. If he ever went to Angkor it is difficult to believe that such an experienced architect would have failed to notice the fracture and show it in his section, nor does it seem likely that they all occurred subsequent to his visit.

Yours faithfully, WM. PITT, *Colonel.*

October 20th, 1925.

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SIR,

PARIS, OR THE FUTURE OF WAR.

When reviews of a book question or condemn its opinions the author is not called on, nor is it meet for him to reply. Nor need he worry, for history has amply proved Quintilian's aphorism "the critics condemn what they do not understand," and when Dr. Johnson said, "The great contention of criticism is to find the faults of the moderns and the beauties of the ancients," he might well have applied it to military literature.

But when facts are challenged the case is different. I refer to the review of "Paris, or the Future of War" in the *R.E. Journal* for September, and as this somewhat heated attack is made in the organ of a corps and an institution where I have received much encouragement in earlier years, and which stand out for progressiveness and freedom of opinion, I have a double incentive to reply.

The main challenge as conveyed in the opening remarks—questionable taste I ignore—is not to my opinions, as expressed in "Paris," but to my facts. To pin down the reviewer to more than one or two definite contradictions is as much as is possible, for instead of doing me the bare justice of outlining the purport of my theme or my main points, he devotes most of his space to a merely declamatory depreciation.

The solitary rock of real criticism beneath this wordy foam appears to be that I have done official military authorities an injustice when I say that during recent generations the military objective in war has been the destruction of the enemy's main armed forces on the battle-field. The reviewer says of me, "His references give an inaccurate impression of phrases of the regulations which he entirely divorces from their context, and from the spirit exhibited on every page of the manuals. For example we are told that in the words of *Field Service Regulations*, the accepted military objective in war is the enemy's main forces on the battlefield. The author is endeavouring to show the blindness of the soldier to the moral objective, forgetting, or possibly not having read, the neighbouring paragraph which describes the first duty of the general staff as being 'to 'appreciate the course of action which . . . will most rapidly influence 'the enemy people in the required direction. This demands . . . a 'careful study of the psychology of the enemy people, of their national 'characteristics, resources, and means of existence.' Such a travesty of facts will be patent to the military student . . ."

To this I would reply that "One swallow does not make a summer," nor does one isolated phrase in *F.S.R.* establish the fact that military authority in the past has seriously studied any other means to victory than the destruction of the enemy's main armed forces.

Having had a considerable share in the writing of manuals I know well, too well, the former official insistence on a meaningless ambiguity of diction and dislike of anything that savoured of definiteness. *Field Service Regulations* have always been truly catholic, worded with such generous vagueness as to give countenance to almost every conceivable course of action, or inaction. "The devil quoting scripture to his purpose" has not a simpler task than a commander seeking to justify himself by picking on one of the many ambiguous or contradictory phrases in the manuals.

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My arguments in "Paris" were based on the general tenor of our past doctrine, not on "phrases divorced from their context," and if R.P.P.-W. seriously maintains that the "armed forces" objective has not dominated our doctrines, I would ask him to mention any part of any manual where other means of subduing the enemy's will to resist are studied and discussed. But to dispose of his accusation that I have travestied facts there is actually no need of argument. His isolated quotation is taken from *F.S.R.* Sect. 5, para. 2. One puff of wind from para. 3 blows it away completely. "In framing a plan of campaign the *ultimate* aim, which is *the destruction of the enemy's main forces*, must always be held in view and all other undertakings subordinated to this." If many phrases in *F.S.R.* are vague this at least is not. Its position in the text might almost have been chosen designedly to "put the lid on" any unconventional searchings, encouraged by the preceding paragraph after other objectives.

And to the evidence of *F.S.R.* itself can be added many others of hardly less authority. In Admiral Custance's book, "A Study of War," which received universal and unstinted adulation from reviewers in the various military journals, so unquestioningly is this dogma embraced that the author opens his chapter, "The Military Aim," with the words "Battle being the decisive act . . . it is evident that the decision is complete when the one armed force has been destroyed in battle . . . Hence, the military aim of each side is to destroy in battle, or to neutralize the action of the opposing armed force."

In this place I am not concerned with the delightfully ingenuous lack of reasoning by which this dogma is postulated without examination—as if not even requiring argument—but merely quoting it to show how completely the "armed forces" objective has dominated and obsessed orthodox military thought.

I will leave it to your readers to decide whose is the "travesty of facts," who "divorces (phrases) from their context and from the spirit exhibited on every page of the manuals." R.P.P.-W.'s criticisms might, perhaps, be termed verbal boomerangs—remarking merely that if such is the value of the reviewer's "facts," such also is likely to be the value of his more nebulous general criticisms.

I am, Sir, Your obedient servant,
B. H. LIDDELL HART.

SIR,

AERIAL SURVEYING.

In the September number of the *Royal Engineers' Journal* appeared a review by me of "Aerial Surveying by Rapid Methods." Towards the close of this article appeared a very rough graph showing the cost and scales of vertical air photography as opposed to ground surveying. I much regret that I did not look at the graph before it was sent off to you. As it appears, the cost is shown along the horizontal (across the page) lines, while the scales are shown on the vertical (up and down the page) line. They should, of course, be reversed. The cost are the vertical and the scales are the horizontal lines.

Yours faithfully, H.St.J.L.W.

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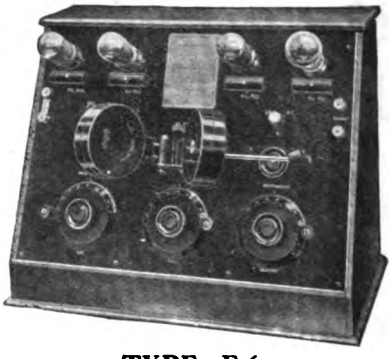
The New Model A. J. S. Receiver is extremely "flexible" and will function satisfactorily on any wave lengths from 150 metres to 20,000 metres. The instrument as shown operates up to 550 metres, beyond that long wave coils are necessary.
Constant Aerial Tuning forms a salient feature of the New Model, and its



power of assimilating weak signals enables it to be used on Frame Aerials.
While embodying all the latest phases in Wireless reception, the A. J. S. New Model, like its prototype, is Supremely Easy and Easily Supreme, and in every respect maintains the A. J. S. tradition of "Quality First."

TYPE F.6.

PRICES:

Receivers Only.		Complete Sets.	
Two-Valve Panel ..	£11 10 0	Two-Valve Set .. .	£16 17 6
Three-Valve Panel ..	£14 17 6	Three-Valve Set ..	£21 13 6
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Table-de-Luxe Receiver. Type T.M.1.

Constructed to contain an A.J.S. Four-Valve Receiver, this Cabinet combines the maximum of wireless efficiency with the minimum of space. Produced in Mahogany it is of distinctly handsome appearance.
It forms a compact and attractive article of furniture when placed upon

any convenient table, and is sufficiently portable to be carried on the seat of a car or boat, to any outdoor function.
The materials and workmanship employed in the production of these Cabinets are of the best throughout, and fully maintain the A.J.S. tradition of "Quality First."

PRICE: With all accessories ready for use, **£35.**
Without accessories .. **£28 15 0.**

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Sir Oliver Lodge's choice after test.

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Junior Loud Speaker.

All Fittings Electro-Plated.

Metal Horn only. Height 19-in.

Black Finish **£1 15 0**
Grained Finish **£1 17 6**

Standard Loud Speaker.

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Mahogany or Oak.. .. **£4 15 0**

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Pedestal Loud Speaker.

Height, 3-ft. 7-ins.

This Model has been designed for those who desire their Loud Speaker a piece of furniture and not merely a mechanical instrument. The design, besides being extremely pleasing to the eye, has worked hand in hand with natural laws with the result that reproduction and tonal quality may be said to be perfect. There is no blare or distortion, in fact sound does not appear to come from the instrument at all but, sweet and clear, from the very air itself.

Price : **£22 10 0**

Cabinet Loud Speaker.

The purity and tone of this Loud Speaker is unsurpassed, due to the specially designed diaphragm unit and horn, combined with the mellowing quality of the mahogany cabinet. This instrument measures just over 11-in. high by 14½-in. broad by 9½-in. deep and the volume is amply sufficient to fill a large room.

Price : **£4 15 0**

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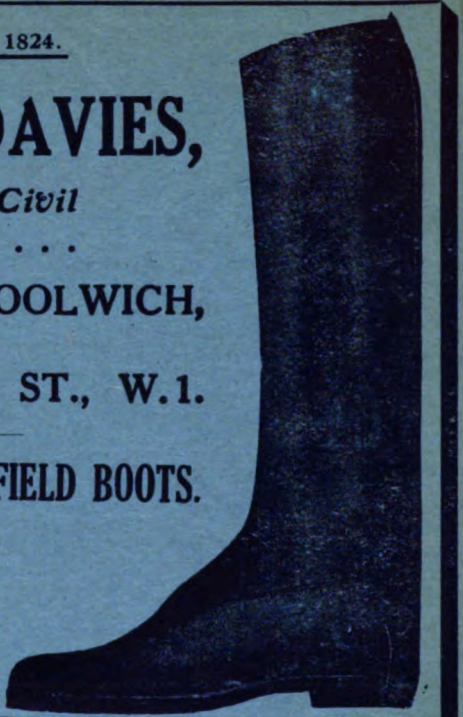

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